EPNOE Sundsvall
2025 Sweden

ABSTRACTS

9th EPNOE International Polysaccharide Conference Sundsvall, Sweden

August 25–28, 2025

Mittuniversitetet
MID SWEDEN UNIVERSITY

Cargill: Your partner in *texture*

Delivering a wealth of solutions for texture, and the technical competence for your optimal application.

Cargill offers the broadest range of texturizing solutions on the market. Our starches offering alone spans from native starches made from corn, wheat, tapioca to a wide range of functional starches; both label-friendly and modified. Furthermore, we supply everything from carrageenan, to lecithin, pectin, and xanthan. All our texturizing solutions are plant-derived.

While our portfolio of solutions is well known in food, several of them have other applications. For example, our scleroglucan gum product range (Actigum™) features solutions for construction, paint, home care, detergents, and cosmetics.

Starches & derivatives: The broadest starch portfolio in the industry, supported by world-class formulation expertise and encompassing native, functional, and modified starches.

Pectin: This label-friendly, plant-based texturizer provides different key functionalities all along the food manufacturing process and in different categories and conditions.

Carrageenan: These water soluble polysaccharides extracted from red seaweeds have thickening, stabilizing, and gelling properties.

Seaweed powder: This label-friendly food ingredient is based on native seaweed without any chemical modification.

Xanthan gum: Our extensive xanthan gum range includes regular and transparent grades, and is available in both powdered and granulated form.

Scleroglucan gum*: Provides a high resistance on shearing and thickens formulations in extreme conditions. Compatible with any surfactants, even cationic ones.

Lecithin: This multi-purpose food ingredient primarily functions as an emulsifier and dispersing agent. Lecithin is also a surfactant.

*Non-food applications.

Partnering for your optimal application
Our broad texturizing portfolio is all backed by application centers offering extensive application know-how and pilot production facilities, helping you create new concepts and tailor existing formulations. For example, we can respond to customer requests by proposing functional systems (INFUSE by Cargill™) that make deliver on-trend products to market faster and more efficiently.

Our world-class formulation expertise means unparalleled technical support, while our focus on cultivating partnerships means that we are dedicated to your success.

About Cargill
Cargill is committed to providing food, ingredients, agricultural solutions, and industrial products to nourish the world in a safe, responsible, and sustainable way.

We do so much more than texture alone.

To discover the other possibilities:
www.cargill.com

Cargill

Empowering Next-Generation Polysaccharide Research with MP-SPR and QCMD

Multi-Parametric Surface Plasmon Resonance (MP-SPR): Precision Kinetics and Surface Interaction Analysis on Interfaces

MP-SPR enables high-resolution, real-time, and label-free investigation of structure–function relationships in complex polysaccharide systems, without water-related artefacts.

Applications include:

- Real-time enzyme kinetics on native or chemically modified cellulose surfaces
- Monitoring the surface functionalization of cellulose
- Quantitative binding analysis of drug–biopolymer interactions
- Measurement of surface coverage and thickness of adsorbed layers
- *In situ* monitoring cellulose film swelling, hydration, and structural changes

BioNavis MP-SPR Navi™ 210A VASA

Quartz Crystal Microbalance with Dissipation (QCMD): Viscoelastic Profiling and Mass Monitoring on Interfaces

QCMD provides real-time measurement of mass changes and viscoelastic properties, offering a comprehensive view of polysaccharide–macromolecule interfaces.

BioNavis QCMD 110

Applications include:

- Monitoring adsorption kinetics of cellulose and its derivatives
- Analyzing enzyme–cellulose interactions for hydrolysis
- Quantifying protein and additive adsorption under varying conditions
- Characterizing film formation, swelling, and viscoelastic properties of cellulose layers

Contact us at info@bionavis.com to learn more!

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- Impurities
- Endotoxins

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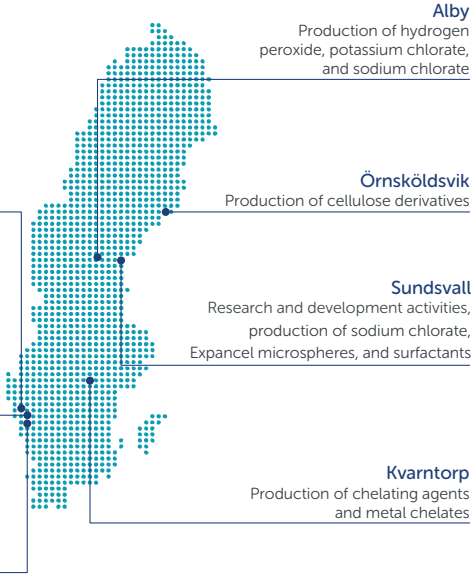

Alby
Production of hydrogen peroxide, potassium chlorate, and sodium chlorate

Stenungsund
Research and development activities, production of ethylene oxide, ethanolamines, ethylene amines, and surfactants

Örnsköldsvik
Production of cellulose derivatives

Bohus
Research and development activities, production of hydrogen peroxide, Levasil Colloidal Silica products, Kromasil products and fine chemicals

Sundsvall
Research and development activities, production of sodium chlorate, Expancel microspheres, and surfactants

Kvarntorp
Production of chelating agents and metal chelates

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Nouryon

Northern Sweden's forests deliver major climate benefits

The forests and forest industry of northern Sweden play a crucial role in the climate transition. In the four northernmost counties, forestry and forest-based industry together deliver a positive climate effect equivalent to around 43 million tonnes of CO_2e each year – roughly the same as Sweden's total annual greenhouse gas emissions.
Read more at sca.com/en/sustainability.

SCA

Unlocking the Potential of Functional Polysaccharides

Polysaccharides are among the most important renewable resources – fascinating polymers with exceptional structural diversity and functional versatility. Through targeted chemical modification, new functionalities can be introduced, enabling precise control over physical, chemical, and biological properties. Yet, only a few derivatives (e.g., certain cellulose esters and ethers) are commercially available. **Posanova GmbH** bridges this gap by providing tailor-made polysaccharides and polysaccharide derivatives with defined molecular architectures to fully exploit these abundant natural resources.

Expertise in Polysaccharide Chemistry - With decades of academic and applied R&D experience, we offer highly specialized products and services, including:

1. Polysaccharide derivatives for thin-layer surface functionalization
2. Reactive polysaccharides for selective coupling (e.g., click chemistry)
3. Polysaccharide-based nanomaterials for drug delivery and sensing
4. Specialty compounds with tailored physical or biological properties
5. Custom synthesis and analytics

Innovative Biomolecule Immobilization

Our proprietary technologies enable efficient and selective immobilization of biomolecules (proteins, antibodies, drugs) and dyes, e.g. onto virtually any surface. By combining self-assembling polysaccharide derivatives with selective coupling reactions, we achieve high binding efficiencies while minimizing non-specific adsorption – a unique advantage for advanced immunoassays.

Engineering Sustainable Biomaterials

We design application-specific biomaterials that integrate the benefits of functional polysaccharides, such as biocompatibility, antimicrobial activity, and processability. Examples include polysaccharide nanoparticles and polysaccharide-based thermoplastics. With our strong R&D heritage, we are ready to support your work with innovative, sustainable polysaccharide solutions.

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Plenary

Plenary lecture 1 - Honorary Plenary, Chemistry, Biology & Physics

2025-08-25
10:40 - 11:20
Plenary lecture 1 - Honorary Plenary, Chemistry, Biology & Physics

PLEN1 - Colloids- new challenges in a historical perspective.

Polysaccharide Colloids
Chemistry, Biology & Physics

Colloids- new challenges in a historical perspective.

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Cellulose is insoluble in water, but since well above 100 years, it has been observed that the combination of high pH and low temperatures provides solvent conditions with a high aqueous solubility of cellulose. In order to understand underlying mechanisms, it was found useful to consider other macromolecular systems like DNA and other polyelectrolytes and surfactant self-assembly. Based on some historical notes on colloid science the general interactions on play are identified. These include the effect of ionization and the peculiar temperature dependence of hydrophobic interactions.

The driving force of dissolution is related to the ionization of cellulose due to a deprotonation of glucose hydroxyl groups. This was qualitatively understood in early work, but in more contemporary literature the interactions behind the resistance to dissolution have been left more open. Recently it has been found that the insolubility of cellulose in water is due to hydrophobic interactions, which are strong due to the amphiphilic character of cellulose. The hydrophobic interaction decreases significantly with decreasing temperature, as well demonstrated for other systems like surfactant self-assembly and protein denaturation. The solubility of cellulose in water can be explained in terms of a balance between ionization effects and hydrophobic interactions; hydrogen bonding on the other hand gives negligible net contribution. The analysis is found to explain the observed features of cellulose dissolution, including a classical phase diagram.

This work has mainly been developed in collaboration with the Sundsvall-Portugal group headed by Magnus Norgren and Bruno Medronho and with Håkan Wennerström in Lund.

Plenary lecture 2 - Materials & Engineering

2025-08-25
11:40 - 12:20
Plenary lecture 2 - Materials & Engineering

PLEN2 - POLYSACCHARIDE-BASED MATERIALS: KEY PLAYERS IN BUILDING A SUSTAINABLE TOMORROW

Sustainable Materials/Circular Economy
Materials & Engineering

Polysaccharide-based materials: Key players in building a sustainable tomorrow

Frollini, E.

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Polysaccharide-based materials are gaining significant traction in various sectors focused on sustainability and innovation, with a robust growth trajectory projected through 2032 (Fig. 1a). Numerous applications can be cited, including biodegradable packaging with additives for antiviral properties, medical applications, water purification, agriculture, construction, and energy storage. Various research groups in Brazil are engaged in the exploration and development of a range of materials derived from polysaccharides, including antimicrobial and antioxidant materials, production of films using regional polysaccharides, hydrogels, composites reinforced with lignocellulosic fibers (where cellulose is the primary component) among others.

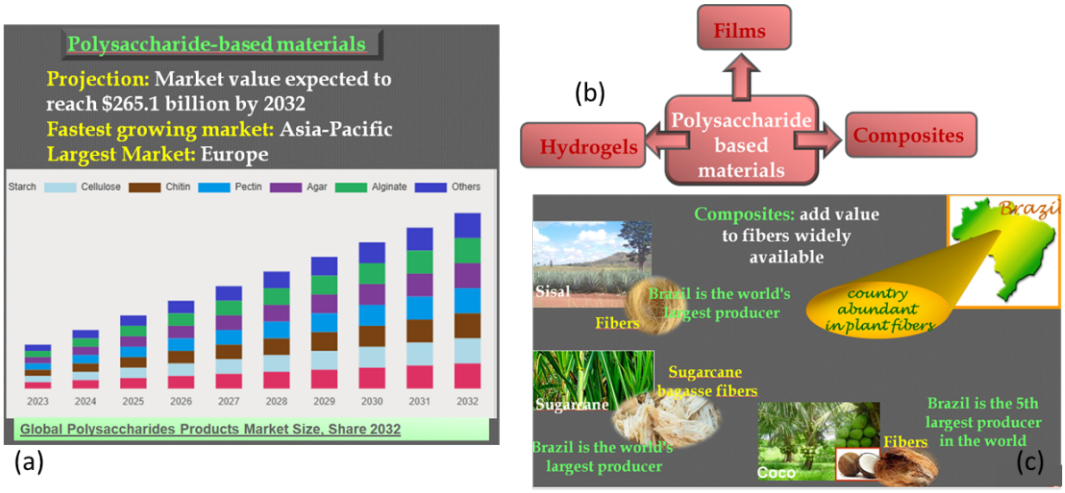

Fig.1. (a)Global market projection for polysaccharide-based (b)Materials investigated at MacromoLignocell (c)Fiber production in Brazil: use in composites

The "MacromoLignocell Group", is currently focusing on developing films, hydrogels, and composites (Fig. 1b), always seeking sustainable processes. Composites are formed parallel to syntheses that occur in molds under temperature and pressure, without solvents, and are reinforced by fibers such as sisal and coconut (Fig. 1c) as short fibers or mats. In the syntheses, the reagents are mostly renewable: (a) cellulose (or lignosulfonate) and castor oil as sources of hydroxyl groups (bio-based polyurethane matrix); (b) citric acid, epoxidized soybean oil, cellulose (polyester/polyether copolymer matrix). Type (a) syntheses are also conducted on the surface of glass plates,

concomitantly forming films with or without additives such as ZnO or SiO2 nanoparticles, which may include additives like ZnO or SiO2 nanoparticles. Alongside cellulose and its derivatives—such as quaternized ethoxylated hydroxyethylcellulose—sources of hydroxyl groups have also included starch and chitosan. Solvents are essential to generating hydrogels. The focus has been deconstructing lignocellulosic fibers using solvents for the polysaccharide fraction, keeping the lignin suspended in the medium, aiming at applications in metal sorption from wastewater and controlled release of fertilizers.

Funding: São Paulo Research Foundation (2020/13703-3), National Council for Scientific and Technological Development (403.494/2021-4).

Plenary lecture 3 - Food & Nutrition

2025-08-26
08:40 - 09:20
Plenary lecture 3 - Food & Nutrition

PLEN3 - POLYSACCHARIDES FROM CANADIAN AGRICULTURAL PRODUCTS: HYDROCOLLOIDS, DIETARY FIBRE AND BIOACTIVES

Dietary Fiber
Food & Nutrition

Polysaccharides from Canadian agricultural products: hydrocolloids, dietary fibre and bioactives

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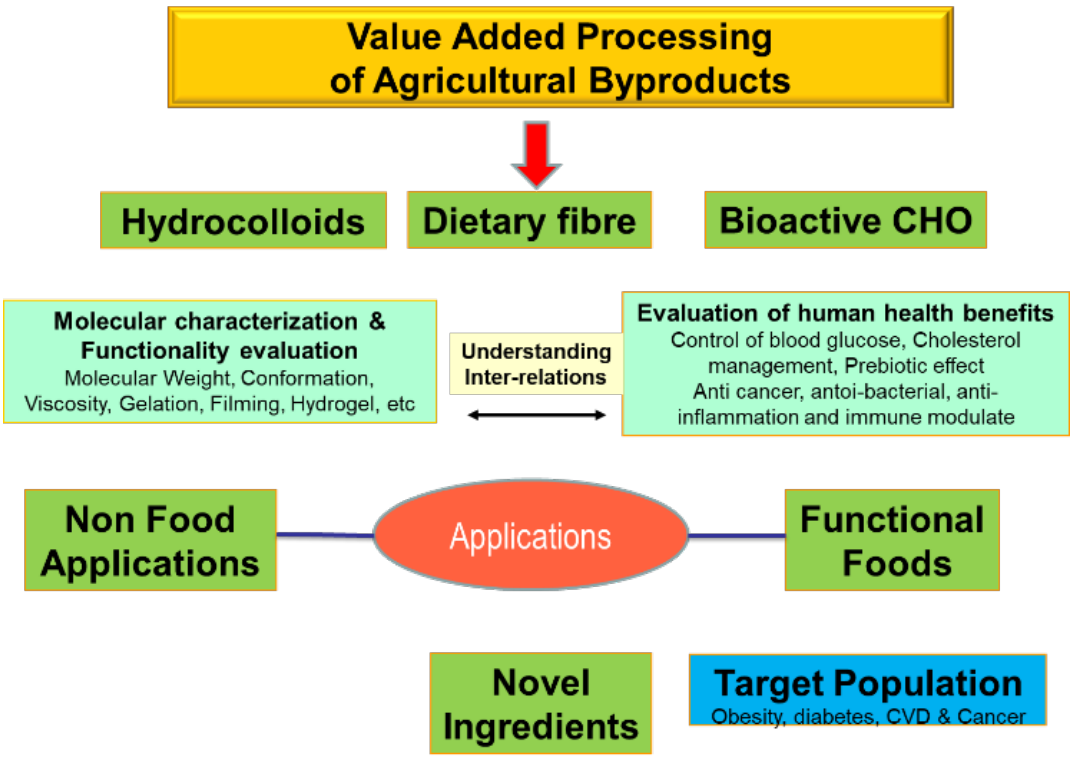
Polysaccharides are abundant in Canadian agricultural products such as flaxseeds, yellow mustard seeds, and cereals including wheat, barley, and oats. Many other crops also contain high levels of polysaccharides, including psyllium, chia seeds, sage, and quinoa. These natural polysaccharides can serve as food hydrocolloids [1,2] and are valuable sources of soluble dietary fiber [3]. Additionally, certain polysaccharides derived from plants and mushrooms have demonstrated bioactive properties, including immune modulation and the potential to prevent certain types of cancer [4,5].

This presentation focuses on polysaccharides from three major Canadian crops: flaxseed, yellow mustard seed, and cereals. It will explore extraction and isolation technologies aimed at developing economically and environmentally sustainable processes for producing polysaccharide-rich food ingredients.

The fine structures of these polysaccharides were characterized using methylation analysis and two-dimensional NMR spectroscopy. Their molecular properties were assessed using high-performance size-exclusion chromatography with light scattering detection (HPSEC-LS), dynamic and static light scattering, and molecular modeling techniques. Rheological behaviors, including flow properties and viscoelastic characteristics, were also evaluated to optimize their functionality in food systems.

To demonstrate the potential of these novel hydrocolloid ingredients, dairy-free and egg-free products were developed, showcasing their application in clean-label food formulations. The presentation will also touch on the emerging uses of polysaccharides as immune modulators and anti-cancer agents, outlining possible directions for future research.



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Plenary lecture 4 - Biomedical & Well-Being Applications

2025-08-26
09:35 - 10:15
Plenary lecture 4 - Biomedical & Well-Being Applications

PLEN4 - POLYSACCHARIDE SELF-ASSEMBLY TO STOP BLEEDING: TRANSLATING A SCIENTIFIC DISCOVERY INTO A USEFUL PRODUCT

Biomedical Devices
Biomedical & Well-being Applications

Polysaccharide self-assembly to stop bleeding:

Translating a scientific discovery into a useful product

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Over the past decade, we have studied derivatives of the polysaccharide chitosan that self-assemble in the presence of vesicles or biological cells. The polymers have a hydrophilic backbone and hydrophobic side-chains. Our initial fundamental studies sought to understand how these polymers interacted with lipid vesicles. We found that the polymer converted an aqueous suspension of vesicles (sol) into a transparent gel. This sol-gel transition of the vesicles was shown to be induced by hydrophobic interactions.

We then studied the same polymer in conjunction with biological cells, with the first studies done with human blood. The polymer again converted liquid blood into a gel – a phenomenon that is reminiscent of blood clotting. Moreover, this gelation could be reversed by cyclodextrins, which are supramolecules with a hydrophobic binding pocket. This was the first example of reversible blood-gelation.

We proceeded to test our polymer on models of bleeding animals. In all cases, the polymer was able to act as a 'hemostatic agent' and arrest severe bleeding. This suggested that the polymer could be used to curtail bleeding, be it on the battlefield, in trauma centers, or during surgery. A startup company was founded by lab members to bring this invention to the market.

In 2021, this company (Medcura Inc.), came out with a version of the product for consumer use, i.e., to rapidly seal and stop bleeding from minor wounds. This product (Rapid-Seal Wound Gel) is available in pharmacies in the USA and has now sold a million units.

Figure 1. Rapid-Seal Wound Gel, a product to stop bleeding from minor injuries.

Plenary lecture 5 - EPNOE Scientific Award Plenary - Chemistry, Biology & Physics

2025-08-27
08:40 - 09:20
Plenary lecture 5 - EPNOE Scientific Award Plenary - Chemistry, Biology & Physics

PLEN5 - STILL NAVIGATING THE COMPLEXITY OF CELLULOSE ANALYSIS

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Still Navigating the Complexity of Cellulose Analysis

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Cellulose continues to be a focal point of our research (boku.ac.at/en/nwnr/chnr) due to its versatility and potential for sustainable applications. Its unique structural and chemical properties make it indispensable in fields ranging from bio-based materials to cultural heritage preservation. At our laboratory, we have been contributing to the growing body of knowledge on cellulose by addressing key challenges and exploring innovative approaches to better understand and utilize this remarkable material. This lecture will provide an overview of our recent work [1-5], highlighting selected advancements in cellulose characterization, processing, and general understanding.

A significant part of our research has focused on improving methods for analyzing cellulose's structural and chemical properties. By refining techniques for molar mass distribution and developing new approaches to quantify and profile chemical modifications in different spatial directions, we have gained deeper insights into the behavior of cellulose during degradation, aging, and functionalization.

We have also explored the use of ionic liquids (ILs) as solvents for cellulose processing and regeneration. Our studies have examined the side reactions and stability aspects of different ILs, contributing to a better understanding of their potential and limitations. In addition, we have looked at the interactions between LPMO enzymes and cellulose fibers, focusing on how enzymatic activity varies across the fiber cross-section. This research has provided new insights into the heterogeneity of enzymatic degradation.

Preservation and aging of cellulose-based materials have long been an important area of our work, particularly in the context of cultural heritage. Our recent studies explored the role of natural and synthetic additives, such as indigo dyes or lignin and their possible role in cellulose aging.

While our contributions represent incremental steps forward, they reflect the collaborative and interdisciplinary nature of cellulose research. By combining advanced analytical tools, chemical methods, and a focus on practical applications, we aim to contribute to the broader understanding and utilization of cellulose. This lecture will provide an overview of these efforts, showcasing how

they fit into the larger context of cellulose science.

1. Melikhov et al. (2025). Dissolving limitations: The power of DMSO activation for cellulose SEC analysis. *Carbohydrate Polymers*, 357, 123443.

2. Budischowsky et al. (2024). Oxidized reducing ends in celluloses: Quantitative profiling relative to molar mass distribution by fluorescence labeling. *Carbohydrate Polymers*, 340, 122210.

3. Sulaeva et al. (2024). Beyond the Surface: A Methodological Exploration of Enzyme Impact along the Cellulose Fiber Cross-Section. *Biomacromolecules*, 25(5), 3076-3086.

4. Melikhov et al. (2024). Stability study of a superbase-derived ionic liquid [mTBNH][OAc] with enhanced cellulose dissolution ability: thermal and natural degradation. *RSC Sustainability*, 2(7), 1994-2004.

5. Rosado M.J., et al. Differences in the content, composition and structure of the lignins from rind and pith of papyrus (Cyperus papyrus L.) culms. (2021) Industrial Crops and Products, 174, art. no. 114226

6. Simon et al. Insights into the borohydride reduction of dialdehyde cellulose: the dilemma of competing reduction and β-elimination reactions. (2023) Cellulose, 30 (13), 8205 - 8220

Plenary lecture 6 - Materials & Engineering

2025-08-27
09:35 - 10:15
Plenary lecture 6 - Materials & Engineering

PLEN6 - PRODUCTION OF CELLULOSE NANOFIBERS USING BACTERIA AND THEIR PROPERTIES AND APPLICATIONS

Sustainable Materials/Circular Economy
Materials & Engineering

Production of cellulose nanofibers using bacteria and their properties and applications

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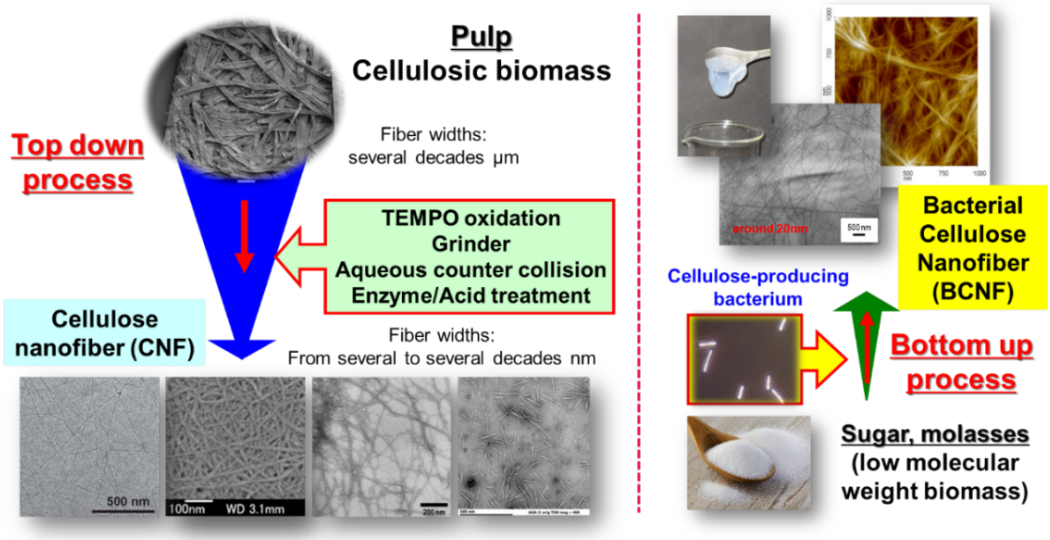
Cellulose nanofiber (CNF) is attracting growing attention as a novel, environmentally sustainable material. Traditionally, CNF is produced from pulp via a top-down process, and a variety of physical and chemical production methods have been reported to date (Fig. 1). In contrast, we have developed a bottom-up process for CNF production using a cellulose-producing bacterium, *Gluconacetobacter intermedius* NEDO-01 [1]. In this approach, the bacterium is cultured aerobically under stirring conditions in a medium containing carboxymethylcellulose (CMC), which functions as a dispersant for the microfibrils. The resulting nanofibrillated bacterial cellulose (CM-NFBC), a kind of bacterial CNF (BCNF), demonstrated excellent dispersibility in water but exhibited rapid aggregation in organic solvents. To address this limitation and expand its potential applications, we developed an amphiphilic form of NFBC, termed HP-NFBC, by replacing CMC with amphiphilic hydroxypropylcellulose (HPC) in a one-step process [2]. This modification significantly enhanced the dispersibility of NFBC in organic solvents. Recently, detailed structural analyses of these NFBCs—including fiber width, fiber length, and viscoelastic properties—have been conducted.



This lecture will provide an overview of bacterial cellulose biosynthesis, highlight the structural and rheological properties of NFBC [3], and explore potential applications that take advantage of its unique characteristics.

Figure 1. Production of CNFs via a top-down process and BCNFs via a bottom-up process.

[1] Kose, R.; Sunagawa, N.; Yoshida, M.; Tajima, K.* One-step production of nanofibrillated bacterial cellulose (NFBC) from waste glycerol using *Gluconacetobacter intermedius* NEDO-01. *Cellulose*, **2013**, *20*, 2971–2979.

[2] Tajima, K.*; Kusumoto, R.; Kose, R.; Kono, H.; Matsushima, T.; Isono, T.; Yamamoto, T.; Satoh, T. One-Step Production of Amphiphilic Nanofibrillated Cellulose Using a Cellulose-Producing Bacterium. *Biomacromolecules*, **2017**, *18*, 3432–3438.

[3] Tsujisaki, H.; Hosokawa, M.; Takasaki, Y.; Yamagata, Y.; Kawabata, Y.; Tatsumi, D.; Seno, S.; Miyamoto, K.; Isono, T.; Yamamoto, T.; Tani, H.; Satoh, T.; Orihara, H.; Tajima, K.* Detailed structural analyses and viscoelastic properties of nano-fibrillated bacterial celluloses. *Carbohydr. Polym. Technol. Appl.*, **2024**, *8*, 100565.

Plenary lecture 7 - Biomedical & Well-Being Applications

2025-08-28
09:35 - 10:15
Plenary lecture 7 - Biomedical & Well-Being Applications

PLEN7 - CUTTING - EDGE RESEARCH ON NATURAL POLYSACCHARIDES IN CHINA

Other
Biomedical & Well-being Applications

Cutting - Edge Research on Natural Polysaccharides in China

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In recent years, Chinese scholars have achieved remarkable breakthroughs in the research of natural polysaccharides. Natural polysaccharides, such as cellulose, chitosan, and trehalose, as renewable resources, exhibit significant application potential in multiple fields including biomedicine, energy storage, and green materials. Chinese researchers have published a series of groundbreaking findings in top - tier international journals like Science [1] and Nature [2,3]. These achievements cover aspects such as the efficient separation and high - value utilization of lignocellulose [2], and the biosynthetic mechanism of chitin [3].

Our team has been focusing on the research of bacterial cellulose. We have made significant progress in precisely controlling the synthesis process to tailor its structural and functional properties [4]. In terms of applications, we have carried out research on biodegradable chip - scale acoustic devices based on bacterial cellulose flexible meta surface metamaterials [5]. These efforts have promoted the innovation and development of natural polysaccharide materials, bridging the gap from fundamental research to practical applications.

1. Meng, X. S., Zhou, L. C., Liu, L., Zhu, Y. B., Meng, Y. F., Zheng, D. C., ... & Yu, S. H. *Science*, **2023,** 380(6651), 1252-1257.

2. Li, N., Yan, K., Rukkijakan, T., Liang, J., Liu, Y., Wang, Z., ... & Wang, F. **2024**. *Nature*, 630(8016), 381-386.

3. Chen, W., Cao, P., Liu, Y., Yu, A., Wang, D., Chen, L., ... & Yang, Q. **2022**. *Nature*, 610(7931), 402-408.

4. Manan, S., Ullah, M. W., Ul-Islam, M., Shi, Z., Gauthier, M., & Yang, G. **2022.** *Progress in Materials Science*, 129, 100972.

5. Chen, K., Li, F., Shi, Z. J., Sun, Q. L., Li, P. Q., ... & Zhu, X. F. **2023**. *Nature Communications*, 14(1), 5319.

Keynote

Keynote 1 - Materials & Engineering

2025-08-25
14:00 - 14:30
Keynote 1 - Materials & Engineering

K1 - CELLULOSIC PLANT FIBERS FOR SEMI-STRUCTURAL AND ECO-FRIENDLY BIOCOMPOSITES

Sustainable Materials/Circular Economy
Materials & Engineering

Cellulosic plant fibers for semi-structural and eco-friendly biocomposites

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Semi-structural composites are exemplified by molded glass fiber composites from short fibers where a Young's modulus exceeding 8-10 GPa and a tensile strength > 100-150 MPa are desirable. For cellulosic fiber materials, a high fiber volume fraction V_f is thus needed for semi-structural applications such as molded panels in transportation, building and general industrial applications. We may define eco-friendly materials by invoking simple criteria such as critical energy demand for primary material production [1], greenhouse gas emissions, recyclability, adherence to green chemistry principles and use of renewable resources.

Structure-property relationships are central for fundamental understanding as well as for materials design and development of polysaccharide materials. Compressed or collapsed cellulosic wood, wood fiber and ramie fiber materials can reach high fiber content and mechanical performance [2] and are analyzed with respect to theoretical micromechanical models, as well as interface [3] - interfacial adhesion [4] and stress transfer mechanisms. Effects on mechanical properties and strain field homogeneity from adding a polymer matrix are then presented, also with examples of chemical recycling of thermosets (polylactide and lignin resins [5]).

Many semi-structural applications require durability under high relative humidity. Since the center of cellulose microfibrils is not accessible to moisture, examples are presented where cellulose bio-composites with polymer matrix show low moisture sorption and small effects from relative humidity on mechanical properties because of nano-structural design and control in the material.

[1] C Montanari, H Chen, M Lidfeldt, J Gunnarsson, P Olsén, LA Berglund, *Small,* **2023,** 19, 2301262

[2] L Zha, M Yan, LA Berglund, Q Zhou, *Biomacromolecules,* **2024**, 25, 3731-3740

[3] H Chen, J Garemark, L Li, M Nero, M Ritter, O Cheung, T Willhammar, I Sychugov, Y Li, LA Berglund, *Small,* **2025**, 21, 2406749

[4] J Wohlert, P Chen, LA Berglund, G Lo Re, *ACS nano,* **2023**, 18, 1882-1891

[5] E Subbotina, P Olsén, M Lawoko, LA Berglund, *ACS Sust Chem & Eng,* **2024,**12, 3632-3642

Keynote 2 - Food & Nutrition

2025-08-25
14:00 - 14:30
Keynote 2 - Food & Nutrition

K2 - STRATEGIES TO INCREASE PREBIOTIC ACTIVITY AND PSYCHOBIOTIC POTENTIAL THROUGH DIETARY FIBRE MODULATION

Dietary Fiber
Food & Nutrition

Strategies to increase prebiotic activity and psychobiotic potential through dietary fibre modulation

Silva, S.P.[a], Gonzalez, A.[b], Roupar, D.[b], Salvador, A.F.[b,c], Bastos, R.[d], Mota, M[a], Luís, M. H.[a], Ferreira, S.S.[a], Alegria, M.J.[e], Nobre, C.[b], Coimbra, M.A.[a], and Coelho, E.*[a]

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Soluble polysaccharides and oligosaccharides are prebiotic compounds that promote the growth of beneficial gut bacteria and contribute to improved health. Industrial juice production results in juices with moderate amounts of soluble dietary fibre because most polysaccharides that constitute the dietary fibre are insoluble. Incorporation of glucanases and pectinases into the juice production process can therefore enrich the juice with soluble fibre and possible prebiotic effects. Apple cloudy juice was only composed of 4 % of fibre (dry basis), mainly pectic polysaccharides. Polysaccharides are mainly retained in pulp (41-37 %) after the industrial juice processing. Hydrolysis of apple pulp with endo- and exo-cellulase released a high amount of material (63.9 %), composed of monosaccharides and a variety of cellulose and xyloglucan oligosaccharides. Hydrolysis with pectin lyase, polygalacturonase, and pectin methylesterase released 57.7 % material composed of pectic polysaccharides and derived oligosaccharides, showing a wide variety of oligosaccharide structures. Fermentation with fecal microbiota released high concentrations of short-chain fatty acids (SCFAs). When compared with non-treated enzymatically pulp, a greater increase in propionate, followed by acetate and butyrate, was observed during fermentation, along with high amounts of γ-aminobutyric acid (GABA) and 5-hydroxytriptophane (5-HTP).

In lignified by-product materials, more drastic strategies need to be used to recover polysaccharides and oligosaccharides with prebiotic activity. Pine nut skin, a by-product obtained during pine nut processing, is a source of insoluble dietary fiber [1]. Subcritical water extraction allowed to obtain an extract rich in pectic polysaccharides and xyloglucans [2]. The fermentation of pectic polysaccharides and xyloglucans had an impact on the microbiota composition similar ($p< 0.05$) to fructooligosaccharides used as positive control, also increasing the abundance of *Bifidobacterium adolescentis*. The core microbiome upon these polysaccharides' fermentation was composed of

multiple butyrate producers, which lead to an increase ($p< 0.05$) of butyrate concentration. Besides, it was observed a microbial utilization selectivity towards xyloglucans in detriment to rhamnose-containing pectic polysaccharides and type II arabinogalactans. The highest concentration of GABA was attained at 24 h of fermentation. Subcritical water extraction of pine nut skin and treatment with pectinases of apple pulp release soluble polysaccharides with prebiotic effect, promoting the growth of psychobiotics which may help to reduce depression, anxiety, and modulate mood.

Acknowledgments: This work was funded by VIIAFOOD-1.2.2. FFV Fruit Fractioning and Valorization from PRR (Programa de Recuperação e Resiliência). Authors acknowledge the FCT financial support through MoodFood project (COMPETE2030-FEDER-00744200) within the COMPETE 2030 and UID/50006 LAQV/REQUIMTE within the PT2020 Partnership Agreement, thank FCT/MCTES for PhD grants (SFRH/BD/136471/2018, SFRH/BD/06268/2021, and SFRH/DB/139884/2018), and research contracts (DL 57/2016/CP1482/CT0038, https://doi.org/10.54499/2023.08855.CEECIND/CP2840/CT0027).

1. S. P. Silva, P. Ferreira-Santos, G. R. Lopes, S. F. Reis, A. González, C. Nobre, V. Freitas, M. A. Coimbra, E. Coelho, Carbohydr. Polym. Technol. Appl., 7 (2024) 100508.

2. S. P. Silva, F. Coreta-Gomes, M. A. Coimbra, E. Coelho, LWT, 197 (2024) 115934.

Keynote 3 - Chemistry, Biology & Physics

2025-08-25
14:00 - 14:30
Keynote 3 - Chemistry, Biology & Physics

K3 - Thermal Degradation of Cellulose Nanomaterials

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

THERMAL DEGRADATION OF CELLULOSE NANOMATERIALS

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Here we present a comprehensive investigation into the thermal degradation behavior of cellulose nanomaterials (CNMs), encompassing both nanofibrillated cellulose and cellulose nanocrystals. By employing a broad suite of analytical techniques, we systematically examine how intrinsic factors such as surface chemistry, crystallinity, and morphology govern the degradation pathways and structural evolution during thermal treatment.[1-3]

Our research characterizes key degradation processes including dehydration, decarboxylation, and decarbonylation, which collectively lead to the formation of condensed aromatic structures. These transformations are examined under various physicochemical conditions and in different dried material forms, with a particular emphasis on the influences of temperature, heating rate, and atmospheric composition. The results reveal that subtle variations in these parameters induce significant changes in the overall thermal stability.[4,5]

Building on these findings, we outline effective strategies to improve the thermal stability of cellulose nanomaterials. By optimizing process parameters—such as surface modification and the selection of appropriate sources—we provide practical guidelines for tailoring the properties of cellulose materials. These strategies are intended to enhance the thermal stability of CNMs, ensuring they remain robust under demanding conditions for applications in packaging, photonics, and advanced nanocomposites.[6]

Finally, an outlook on future research directions is provided. We emphasize the need for comprehensive studies on the thermal stability of cellulose nanofibrils and other cellulose materials, as well as the relatively underexplored behavior of chitin nanomaterials. Leveraging our mechanistic insights, future work should focus on optimizing processing methods to enhance thermal stability under demanding conditions. Such advancements will pave the way for innovative, high-performance materials tailored for applications where thermal performances play a key role.

[1] D'Acierno, F.; Hamad, W. Y.; Michal, C. A.; MacLachlan, M. J. (2020). *Biomacromolecules*, *21*, 3374-3386.

[2] Vanderfleet, O. M.*; D'Acierno, F.*; Isogai, A.; MacLachlan, M. J.; Michal, C. A.; Cranston, E. D. (2022). *Chem. Mater.*, *34*, 8248-8261.

[3] D'Acierno, F.; Hamad, W. Y.; Michal, C. A.; MacLachlan, M. J. (2021). *Biores. Technol. Rep.*, *16*, 100838.

[4] D'Acierno, F.; Ohashi, R.; Hamad, W. Y.; Michal, C. A.; MacLachlan, M. J. (2021). *Carbohydr. Polym.*, *272*, 118468.

[5] D'Acierno, F.; Bakrani, K.; Hamad, W. Y.; Michal, C. A.; MacLachlan, M. J. (2022). *ACS Sustainable Chem. Eng.*, *10*, 8715-8724.

[6] D'Acierno, F.; Michal, C. A.; MacLachlan, M. J. (2023). *Chem. Rev.*, *123*, 7295-7325.

Keynote 4 - Biomedical and Well-Being Applications

2025-08-25
14:00 - 14:30
Keynote 4 - Biomedical and Well-Being Applications

K4 - DIALDEHYDE POLYSACCHARIDE-POLYPYRROLE COPOLYMERS: GREEN SYNTHESIS AND PROMISING BIOMEDICAL PROPERTIES

Biomedical Devices
Biomedical & Well-being Applications

IMPACT of molecular weight of schizophyllan on its biological activity and modifications

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Schizophyllan (SPG), a β-Glucan from the fungus *Schizophyllum commune* (Figure 1) exhibits notable biological activity, having strong immunomodulatory and anticancer properties. The biological effects of SPG are deemed to be related to its triple-helical structure and molecular weight (expressed by weight-average molecular weight, M_w), with single-strand SPG with $M_w < 50$ kDa being inactive [1]. However, the high molecular weight of native SPG and its often broad molecular weight distribution hinder its solubility in aqueous media and limit its utility in a pharmaceutical context [2].

Here, the impact of M_w of SPG on its properties and biological activity was investigated in detail. Initially, the wet-jet milling technique was employed to reduce both the M_w and dispersity of SPG, thereby enhancing water solubility and improving uniformity. Next, SPG samples with different M_w (between 4500 kDa and 250 kDa) were characterised, and their biological properties, including their affinity for different cell membrane receptors, were evaluated. Contrary to expectations, the biological activity did not uniformly decrease with M_w, indicating that some of the lower molecular weight fractions might have an interesting potential for biomedical applications and further modifications, while others ($M_w \sim 250$ kDa) showed a sharp decrease in activity.

Moreover, oxidative modifications of the best candidates were performed, the reaction was optimised, and their properties were evaluated. Results show that SPG with M_w as low as 300 kDa can be used to prepare interesting biologically active derivatives.

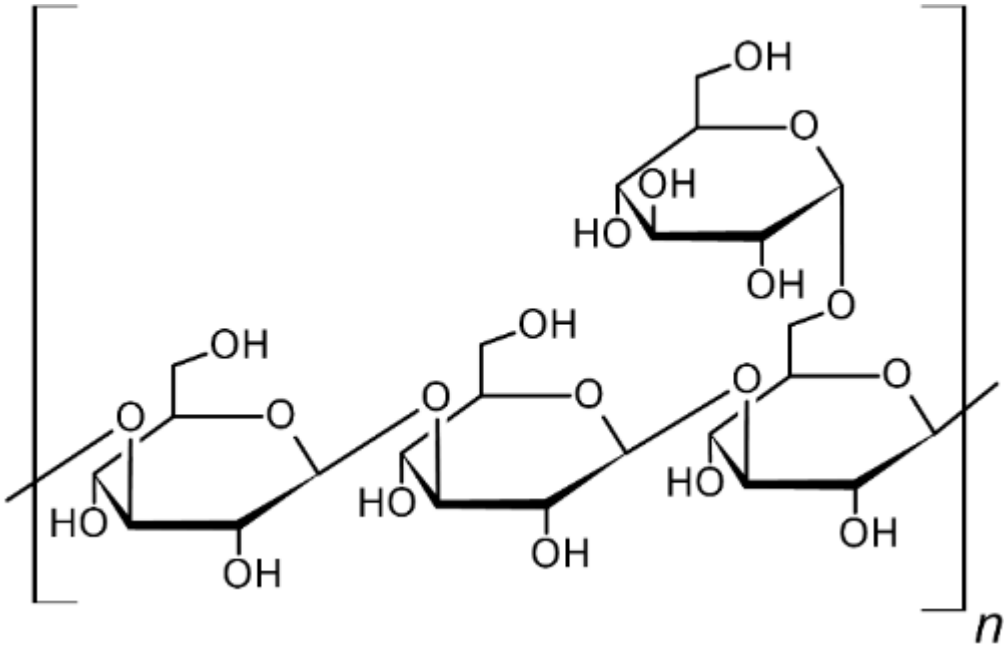

Figure 1. Structure of schizophyllan.

Acknowledgements: *The authors thank the Ministry of Education, Youth and Sports of the Czech Republic – DKRVO RP/CPS/2024-28/001, the Ministry of Health of the Czech Republic – AZV NW24-03-00331 and the Internal Grant Agency of Centre of Polymer Systems in Zlín – IGA/CPS/2025/001 for financial support.*

[1] E. Ansari, H. Alvandi, S. Kianirad, A. Hatamian-Zarmi, Z. B. Mokhtari-Hosseini, *Carbohydrate Polymers* **2025**, *348*, 122770.

[2] Zhang, Y.; Kong, H.; Fang, Y.; Nishinari, K.; Phillips, G.O. *Bioactive Carbohydrates and Dietary Fibre*. **2013**, *1,* 53–71

Keynote 5 - Materials & Engineering

2025-08-25
14:00 - 14:30
Keynote 5 - Materials & Engineering

K5 - DESIGNING CHIRAL TEMPLATES WITH CELLULOSE NANOCRYSTAL ALLOMORPHS AND POLYMER END-TETHERING

Nanostructured Materials
Materials & Engineering

DESIGNING CHIRAL TEMPLATES WITH CELLULOSE NANOCRYSTAL ALLOMORPHS AND POLYMER END-TETHERING

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Liquid crystal (LC) templating is a widely applied technique to guide the formation of highly ordered and functional materials by leveraging the self-assembling properties of liquid crystals [1]. Anisotropic colloids, such as cellulose nanocrystals (CNCs), are an especially unique LC system since their lyotropic chiral nematic LC phases are preserved in the solid state upon evaporation-induced self-assembly, generating photonic films with feature sizes interacting in the UV–visible region. Inspired by the well-defined patterns produced by microphase separation of amphiphilic block copolymers [2] and the development of chiral nematic mesoporous materials [1], we investigate the synthesis and self-assembly of colloidal analogues of block copolymers based on CNC allomorphs produced from various sources [3]. These materials are produced by a combination of crystal allomorph transformations and reducing end group (REG) modification with nonionic hydrophilic polymers. In addition to cellulose I nanocrystals (CNC-I) with parallel chain arrangements, we apply Mercerization of cellulosic fibers, followed by acid hydrolysis, to produce CNC-II with anti-parallel chains. Through treatment of CNCs with ethylenediamine, we further generate metastable CNC-III allomorphs. Over the last few years, we have studied the covalent attachment of poly[2-(2-(2-methoxy ethoxy)ethoxy)ethyl acrylate] ($POEG_3A$) [4] and methoxy polyethylene glycol (mPEG) to the REGs of CNC allomorphs, via grafting onto approaches, to correlate building block morphology to LC phase characteristics, including changes in critical concentration for LC phase formation, domain size and pitch (Figure 1). We foresee the use of end-tethered CNC allomorphs as templates for assembling chiral metamaterials with helicoidal morphologies for applications in plasmon-enhanced spectroscopic analysis of chiral compounds.

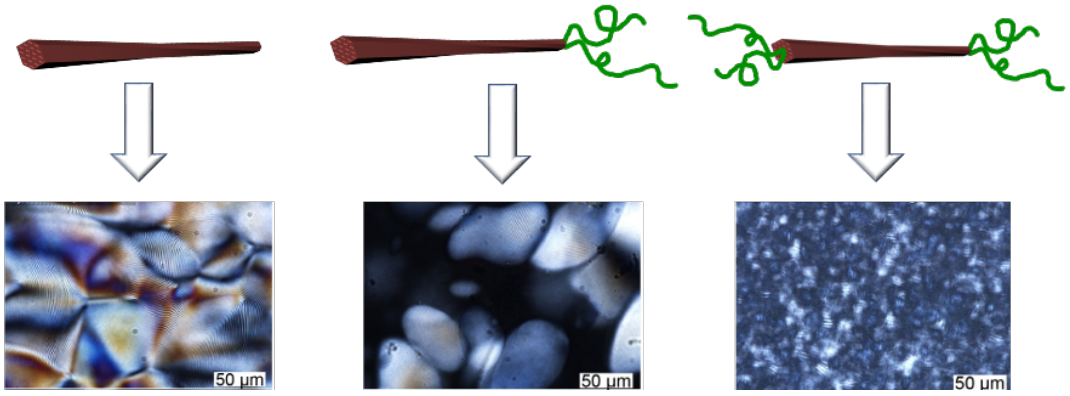

Figure 1. Illustrations and polarized optical microscopy (POM) images of aqueous suspensions of CNC-I (left), asymmetric CNC-I-RE-*g*-POEG$_3$A (center) and symmetric CNC-II-RE-*g*-POEG$_3$A (right).

[1] Giese, M., Blusch, L.K., Khan, M.K., MacLachlan, M.J., *Angew. Chem. Int. Ed.* **2015**, 54, 2888-2910

[2] Z. Wang, C. L. C. Chan, T. H. Zhao, R. M. Parker, S. Vignolini, *Adv. Optical Mater.* **2021**, 9, 2100519

[3] Zoppe, J.O., *Acc. Mater. Res.* **2024** *5* (4), 385-391

[4] Delepierre, G., Traeger, H., Adamcik, J., Cranston, E.D., Weder, C., Zoppe, J.O., *Biomacromolecules* **2021** *22* (8), 3552-3564

Keynote 6 - Materials & Engineering

2025-08-26
11:00 - 11:30
Keynote 6 - Materials & Engineering

K6 - NEXT GENERATION OF MYCELIUM COMPOSITES: FROM WASTE TO COMPOSITES

Sustainable Materials/Circular Economy
Materials & Engineering

Keynote 7 - Food & Nutrition

2025-08-26
11:00 - 11:30
Keynote 7 - Food & Nutrition

K7 - FROM SUGARS TO FIBRES AND STARCHES: A PHYSICO-CHEMICAL FRAMEWORK FOR UNDERSTANDING NON-CHARGED POLYSACCHARIDE FUNCTIONALITY

Other
Food & Nutrition

From Sugars to Fibres AND Starches: A Physico-Chemical Framework for Understanding Non-Charged Polysaccharide Functionality

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Polysaccharides exhibit a broad spectrum of functionalities in food, from thickening liquids to forming gels. Due to their molecular diversity, a unifying physico-chemical understanding of their functionality remains a challenge. In this contribution, we present a thermodynamic and rheological framework attempting to provide a universal description of polysaccharides functionality. This conceptual framework is based on 1) the volumetric density of hydrogen bonds, related to glass-transition temperature of the system, 2) the hygroscopicity, as captured by the Flory-Huggins interaction parameter, and 3) the scaling of rheology with T_g/T. These parameters provide the essential interactions between polysaccharides and water, and offer a predictive basis for understanding their functional role across food applications.

We first demonstrate how these descriptors govern key material properties such as viscosity and hygroscopicity, allowing classification of sugars, oligosaccharides, and soluble fibres along a common physico-chemical axis. Extending this framework to interactions with other biopolymers, we show how sugars and soluble fibres interact with biopolymers like proteins and starches, affecting their melting transitions following Flory-Huggins theory and network development (e.g. gluten). The balance between hydrogen bond density and water affinity explains the dual role of fibres as plasticizers and structure modulators, with deviations related to phase separation phenomena. The conceptual framework is further applied to starches from diverse botanical sources, showing how gelatinization and gelation behaviours collapse onto universal melting and scaling diagrams when expressed as functions of hydrogen bond density and T_g/T. These findings rationalize observed differences between cereal and tuber starches, and provide predictive insight into their performance under various hydration and solute conditions. Finally, we illustrate how this physico-chemical approach enables rational design of food systems. Through enzymatic modification or blending strategies, polysaccharide structures can be tuned to deliver targeted functionalities—such as texture control, sugar replacement, or moisture regulation—using sustainable fibre-rich sources.

This presentation aims to provide a comprehensive molecular-to-macroscopic understanding of non-charged polysaccharides towards practical relevance for innovation in food formulation and ingredient design.

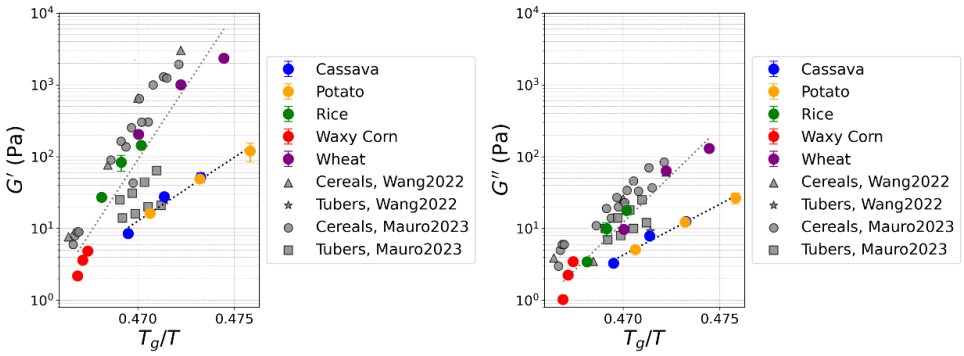

Figure 1.
G’ and G’’ plotted as function of T_g/T computed from amylose concentration in starch gels.

Keynote 8 - Chemistry, Biology & Physics

2025-08-26
11:00 - 11:30
Keynote 8 - Chemistry, Biology & Physics

K8 - SPATIAL ARRANGEMENT OF CELLULOSE RELATED TO PROCESSING AND PROPERTIES

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Spatial arrangement of Cellulose related to processing and properties

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Due to the intrinsic rigidity and elongated shape of the molecule, cellulose has minimal freedom in its condensed state, and the spatial arrangement is primarily dictated by biosynthesis or processing conditions when solution-processed. The straight backbone structure results in highly anisotropic mechanical properties of the chain segment, which influences both the swelling behavior and macroscopic mechanical behaviors. Knowledge of structure formation is crucial for maximizing the potential of abundant resources with minimal energy input.

Native cellulose, composed of microfibrils or nanofibers with alternating crystalline and amorphous domains along the chain direction, has been a popular vision for many decades. Indeed, native cellulose fibers can lose their strength drastically due to hydrolysis, primarily due to the concentration of defects. However, there has been accumulating evidence that defects arise in the drying process of the cellulose and are not intrinsic properties of the nascent higher plant cell wall [1]. The removal of hemicellulose and lignin from the cell wall, which impeded cellulose from collapsing on each other, combined with the strong capillary force of evaporating water, would result in tight lateral aggregation and concentration of local strain, which in turn allows the production of "cellulose nanocrsytals," or CNCs, by strong acid hydrolysis.

Despite the large variety of plant morphologies, small-angle X-ray scattering suggests that the lateral dimension of cellulose microfibrils, when embedded in hemicellulose and lignin, remains constant over a wide range of species, consistent with the 18 chains produced by the rosette consisting of 6 granular objects that hold three catalytic sites each [2]. The removal of substance in the interstice of cellulose microfibrils results in the compaction of the system, which inevitably deforms the crystals [3]. Indeed, despite the high modulus along the chain direction, the mechanical properties of the crystal are highly anisotropic [4] and can undergo local plastic deformation through chain sliding[5] and storage of strain energy [6]. The remodeling due to purification and drying results in a higher volume fraction of cellulose and, consequently, a stiffer structure. However, it can also lead to a heterogeneous stress distribution, which is detrimental to the resistance.

The processing of cellulose involves the incorporation and removal of small molecules, such as water, which enables large deformation. However, the removal of these molecules will result in significant deformation and strain redistribution, depending on the spatial arrangement of the entangled system at the moment of freezing. Given this, spacer molecules that have enough freedom to adapt to local large deformation can play a key role. The extractives, lignin, and hemicelluloses in

wood play a similar role and can provide insights for the development of high-strength materials.

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Keynote 9 - Biomedical & Well-Being Applications

2025-08-26
11:00 - 11:30
Keynote 9 - Biomedical & Well-Being Applications

K9 - Chitosan-Alginate based magnetic hydrogels: Preparation and characterization of for doxorubicin delivery

Drug Delivery Systems
Biomedical & Well-being Applications

Chitosan-Alginate based magnetic hydrogels: Preparation and characterization of for doxorubicin delivery

Oliveira[1], T. P., Silva[1], T. P. S., Silva[1], J. G. V., Costa[1], P. M., Santos[1], F. E. P., **Muniz[1,2,3], E. C.**

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Abstract: Magnetic hydrogels are considered promising systems for drug delivery due to their high adsorption capacity, biocompatibility, strong magnetic properties, and rapid responsiveness that can be tuned by external magnetic fields [1]. These materials are developed by incorporating magnetic moieties, such as ferrites nanoparticles (NPs), into the hydrogel matrix, imparting magnetic stimulus sensitivity to conventional hydrogels [2]. Spinel-type ferrites exhibit relevant characteristics, including high chemical, thermal, and magnetic stability, making them suitable for biomedical applications [3]. In this study, polysaccharides-based hydrogels constituted by chitosan and alginate were prepared by physical crosslinking in presence of ferrites NPs ($CoFe_2O_4$ or $NiFe_2O_4$). The NPs were synthesized through a green synthesis methodology using jatobá leaf extract (*Hymenaea courbaril*). Different formulations (chitosan /alginate/NPs) and diverse routs for hydrogels preparations were used. The as-obtained materials were characterized for evaluating polymer-nanoparticle interactions, swelling capacity at different pH values, and sustained release of doxorubicin (DOX). Raman spectroscopy revealed characteristic vibrational modes of both polysaccharides and ferrites, confirming their interaction and the formation of magnetic hydrogels. Swelling tests showed pH-dependent behavior, with all samples exhibiting greater swelling at pH 7.4. The *in vitro* DOX release demonstrated distinct profiles considering different hydrogels formulations and being the release rate dependent on the pH of the medium and presence of magnetic field was also observed. Thus, the as-obtained magnetic hydrogels prepared in this project show potential for DOX delivery, being responsive to external stimuli.

Keywords: Magnetic hydrogels. Chitosan. Alginate. Ferrites. Drug delivery.

Acknowledgments: TPO thanks to Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão, Brazil (FAPEMA, BD-02593/21 - 13/2021) for the doctoral fellowship. This research was also supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, Brazil) [Grant #406973/2022-9, #307429/2018-0 and #408767/2021-9).

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Keynote 10 - Materials & Engineering

2025-08-26
11:00 - 11:30
Keynote 10 - Materials & Engineering

K10 - Strategies to turn waste and side streams into high-quality cellulosic fibers

Textile, Pulp, Paper & Packaging
Materials & Engineering

Strategies to turn waste and side streams into high-quality cellulosic Fibers

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Driven by efforts to foster material circularity and bioeconomy concepts, the use of waste and side streams as substrate for cellulosic products has received increased attention during the past years. Although these substrates are often available in large quantities and at very low price, they usually require tailored pretreatment protocols to remove impurities that can disturb the production process or compromise the product quality. These additional process steps can affect significantly the overall economic viability of waste materials.

Herein, we present the use of various waste materials as substrate for Lyocell-type fibers. Thus far, our investigations have focused on the production of novel cellulosic Ioncell® fibers from textile waste materials such as cotton roll towels [1], hemp [2], viscose or Modal fibers. Recently, we extended the variety of materials and started to investigate more complex ligno-cellulosic materials. Discarded banknotes, non-recyclable books and even wood from an excavated ship built in the 17th century were processed into high-quality textile fibers (Figure 1). Each substrate contained one or more non-cellulosic material that required removal strategies. The refining strategy were built on existing processes. For instance, kraft pulping was connected to floatation technology to remove polymeric constituents (e.g., lignin and hemicellulose) and particulate matter (e.g., pigment dyes), respectively. The resulting cellulose-rich pulp was spun into textile fibers using the dry-jet wet spinning-based Ioncell® technology. The resulting fibers were characterized comprehensively and further converted to textile prototype products.

This study will guide future recycling strategies for challenging multi-component waste materials.

Figure 1. Waste streams used as feedstock: banknotes to fibers (left), books to fibers (middle), excavated ship wood (right).

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Keynote 11 - Chemistry, Biology & Physics

2025-08-27
11:00 - 11:30
Keynote 11 - Chemistry, Biology & Physics

K11 - On the hornification of cellulose-rich materials

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

On the hornification of cellulose-rich materials

Lars Wågberg, Tobias Benselfelt, Farhiya Alex Sellman and Nadia Asta

The permanent loss of swelling in water of cellulose-rich fibres, from wood, upon drying and rehydrating has been a large practical problem for the papermakers and a scientific enigma for researchers over the years. Since fibres are small, heterogeneous, usually being composed of both earlywood and latewood, and being delignified in different ways it has been difficult to find general, molecularly based scientific explanations to the hornification process. Explanations such as covalent bond formation, H-bonding and kinetically locked states has been brought forward, many times with a minimum of systematic studies on a molecular level with spectroscopic support or help. During the last decades there has been a rapid development of model materials mimicking the properties and structure of “native” cellulose-rich fibres in combination with high resolution, measuring techniques allowing us to take giant leaps to really study molecular interactions. In our work we have been using model materials in the form of flat model surfaces (from regenerated cellulose or transparent nanopapers from fibrils), regenerated cellulose beads and filaments made from cellulose nanofibrils. These materials have been subjected to different types of studies all aimed at clarifying the molecular mechanism behind hornification of cellulose-rich materials. The nanopapers, the beads and the filaments were all prepared in aqueous media, dried and reswollen in water to clarify the degree of hornification after drying and after heating, when dried, for different times. They were also liquid exchanged to different liquids , dried and re-swollen both after drying and after heating, when dried, for different times. In another set of experiments the cellulose beads were pressed against a flat cellulose film and very well controlled mechanical conditions and at different RHs in the surrounding air. The results show that the materials can be hornified after being dried even from aprotic solvents indeed indicating that the hornification is not dependant on hydrogen mediating solvents. The results also show that when exposed to, even, low moisture levels the cellulose model surfaces are showing a significant plastcization thereby allowing for the creation of a large molecular contact zone between the materials and the development of a huge hysteresis upon loading and unloading. These results will be discussed in terms of molecular contact zones, molecular interactions and migration of polymers across interfaces.

Keynote 12 - Chemistry, Biology & Physics

2025-08-27
11:00 - 11:30
Keynote 12 - Chemistry, Biology & Physics

K12 - PROBING THE COLLOIDAL BEHAVIOR OF A PLANT CELL WALL ENZYME IN A HIGHLY CONSTRAINED MODEL SYSTEM

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

Probing the colloidal behavior of a plant cell wall enzyme in a highly constrained model system

Isabelle Caprona, Estelle Bonnina, Mélanie Marquisa, Camille Alvaradoa, Suzanne Lafon[b], Teresa Lopez-Leon[b], Frédéric Jamme[c], Hugo Voisina

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Understanding the specific interaction of cell wall polysaccharides degrading-enzymes with their substrates is of fundamental and practical interest. Such interactions are difficult to unveil in real-life conditions due to the structural complexity of the plant cell wall. In this work, we present complex and highly confined model systems of cholesteric cellulose nanocrystal suspensions reaching dimensions close to those found in the plant cell wall. Cellulose-xyloglucan (XG) assemblies of various surface chemistries were studied, allowing to probe the interactions and diffusion behavior of a glucanase both in diluted dynamic conditions and in an organized and concentrated (110 - 140 g/L) cholesteric environment.

QCM-D and synchrotron source-deep UV analyses showed that XG adsorbed in a flat and extended conformation changed the glucanase interaction with the polysaccharides from attractive to repulsive. It revealed the free diffusion of a glucanase towards the less concentrated and organized areas exclusively when XG was present. It demonstrates that increased complexity of medium (mixture of soluble and insoluble polysaccharides) strongly influences the nature of the interaction of enzymes with solid components. This work provides new insights on the influence of the interaction of a protein with a substrate on its transport in a constrained environment.

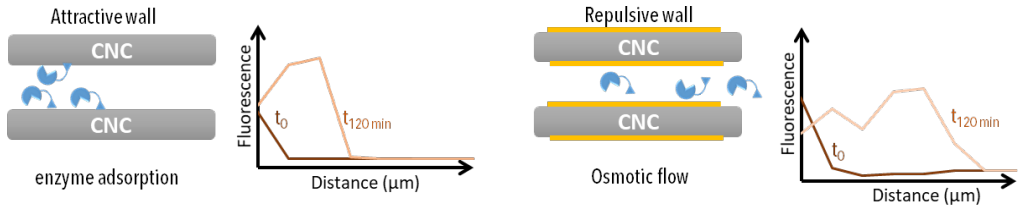

Figure 1. Adding XG strongly influences the diffusion of enzymes in constrained conditions

[1] .: Voisin H.P. et al. JCIS under review ??

Keynote 13 - Materials & Engineering

2025-08-27
11:00 - 11:30
Keynote 13 - Materials & Engineering

K13 - HOW RHEOLOGY HELPS MAKING 3D PRINTED ADDITIVE- AND CROSSLINKER-FREE BIO-AEROGELS

3D Printing and Additive Manufacturing
Materials & Engineering

How rheology helps making 3D printed additive- and crosslinker-free bio-aerogels

Negrier, M., Yu, S., Castellani, R., Pereira, A., Valette, R., Budtova*, T.

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Bio-aerogels are nanostructured low-density and high-specific surface materials, and the majority are based on polysaccharides. Two main pathways are used to make bio-aerogels: either by polymer dissolution or from a suspension of "nanoparticles" (nanocellulose, nanochitin), followed by solvent exchange and drying with supercritical CO_2. In our work, we consider the first pathway.

Till now, the majority of bio-aerogels made by dissolution/solvent exchange route are prepared in "simple" shapes (cylinders, disks) by molding [1], or by making particles (dropping, prilling, emulsification) [2, 3]. However, certain applications, for example, biomedical, may require complex shapes and hierarchical porosity. This can be achieved by 3D printing.

The goal of our work was to use Direct Ink Writing to print self-standing solutions with no crosslinking and no additives, as they may alter sensitive applications. Two examples will be demonstrated: cellulose/ionic liquid solutions and aqueous carboxymethyl cellulose (CMC) solutions. In both cases we adjusted the rheological properties of solutions to obtain yield-stress shear thinning fluids. For cellulose, this was done by tuning its solubility. After obtaining various complex-shaped structures based on dissolved polysaccharides, aerogels were made and characterized. The density of solid parts was around 0.1 g/cm^3 and the specific surface area was 140 m^2/g for CMC aerogels [4] and 250 m^2/g for cellulose aerogels.

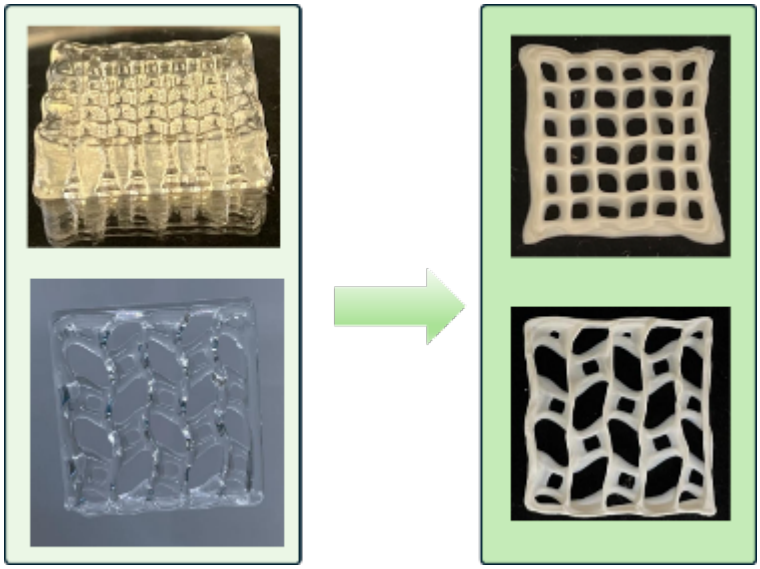

Figure 1. Printed CMC solutions and corresponding aerogels [4]

Acknowledgements

We acknowledge the financial support from CARNOT MINES and China Scholarship Council, IFF for providing CMC samples, and Région Sud – Provence-Alpes-Côte d'Azur for supporting the acquisition of scanning electron microscope. We warmly thank J. Jaxel (PERSEE, Mines Paris, France) for supercritical drying and G. L. Tian (Ecole Polytechnique, France) for coding printing pressure calibration.

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Keynote 14 - Materials & Engineering

2025-08-27
11:00 - 11:30
Keynote 14 - Materials & Engineering

K14 - Proposal of upcycle recycling process using an extremely trace amount of amphiphilic cellulose nanofibrils prepared by aqueous counter collision

Sustainable Materials/Circular Economy
Materials & Engineering

Proposal of Upcycle recycling process using an extremely trace amount of amphiphilic cellulose nanofibrils prepared by aqueous counter collision

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Over the past decade, cellulose nanofibrils (CNFs) have attracted considerable attention as a versatile green platform aiming at bio-based industrial materials, due to their high specific surface areas, high mechanical strength, and low coefficients of thermal expansion. In particular, owing to their excellent material properties, it is expected that they will be used widely as fillers for nanocomposites, and stabilizers for Pickering emulsions.

Two decades ago, Kondo et al proposed an aqueous counter collision (ACC) process that enables the rapid preparation of CNFs as an aqueous dispersion solely by impinging a pair of water jets containing the raw materials [1]. The resulting CNF (=ACC-CNFs) by ACC process was found to have amphiphilic nature on fiber surfaces, in which two kinds of faces with different nature are present along the entire fiber axis [2]. This emergence of the amphiphilicity was proved due to the unique downsizing mechanism of an aqueous counter collision (ACC) process [3].

Recently, Kondo et al. also have found that the amphiphilic ACC-CNFs can coat hydrophobic surfaces of polypropylene (PP) particles easily by shaking in their aqueous suspension. Further, the CNF-coated iPP microspheres allows simple injection molding process to induce fusion of the individual microspheres and generate a three-dimensional framework of ACC-CNFs resembling a plant cell wall structure (see Fig.1 left) [4]. This framework with the ultralow amounts (0.03 wt% / PP) of amphiphilic ACC-CNFs has induced to improve the impact shock resistance of the plastic at most by 1.8 times (depending on the atmospheric conditions), which is a striking effect.

This paper will report the attempts to employ the above material design for establishment of upcycle plastic recycling system. Namely, every recycling of PP, the coating ACC-CNFs are supposed to be accumulated to result in enhancement of the properties of each recycled PP plastics “up and up”.

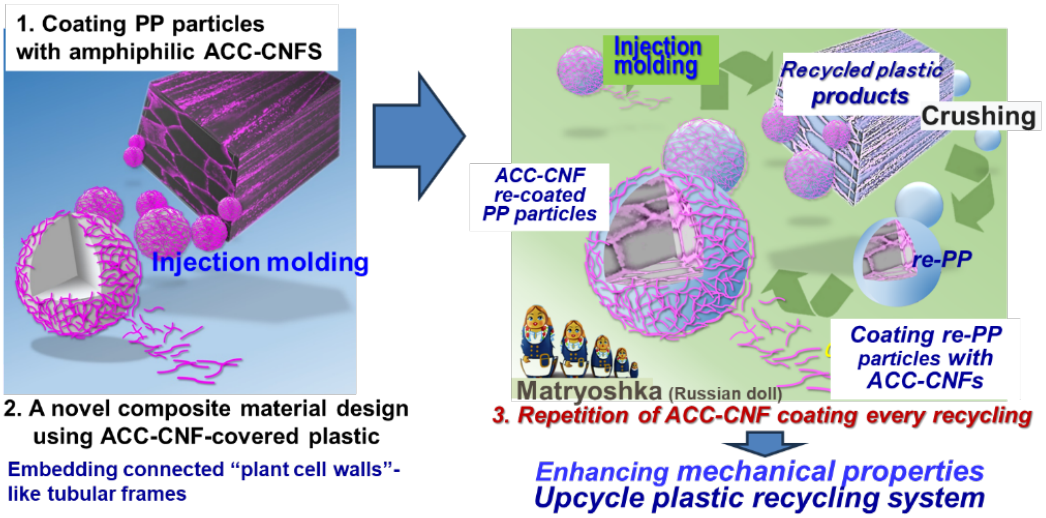

Figure 1. Strategy for upcycle recycling (Up and UP) system

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Keynote 15 - Materials & Engineering

2025-08-28
11:00 - 11:30
Keynote 15 - Materials & Engineering

K15 - ADVANCING BIORENEWABLE TECHNOLOGIES THROUGH THE LENS OF COLLOID SCIENCE

Materials & Engineering

Advancing Biorenewable Technologies Through the Lens of Colloid Science

Orlando J. Rojas*[a]

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Most developments in colloid science have relied on mineral and petroleum-derived polymers that achieve well-defined chemical and dimensional characteristics. Unfortunately, it is challenging to attain such control when considering renewable nanoparticles. Herein, I introduce some emblematic cases associated with our recent work that highlight the great possibilities of biobased-colloids obtained from plant biomass and residues. I show the control over renewable particle size and shape heterogeneity, highly relevant to the design of photonic coatings and supracolloidal assemblies. We propose a pathway toward selectable biobased particle size and physicochemical profiles. The correlation that exists between size and physicochemical characteristics (molar mass, surface charge, bonding and functional groups, among others) is offered as a powerful route to identify technological uses that benefit from the functionality and cost-effectiveness of biogenic particles. I further discuss processing routes that transforms low-value, residual biomass and use examples to synthesize all-green materials from polysaccharide and aromatic structures. These are demonstrated for their recyclability and biodegradability in natural environments, addressing the limitations of circularity and end of life of non-renewable products. Given the low-cost of the raw materials, their natural micro-structural design and self-adhesion, this presentation shows fully sustainable alternatives to products based on non-renewable carbon. The impact of related technologies is shown to depend on our ability to control water interactions and gelation phenomena.

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Keynote 16 - Chemistry, Biology & Physics

2025-08-28
11:00 - 11:30
Keynote 16 - Chemistry, Biology & Physics

K16 - UNVEILING THE UNUSUAL FEATURES OF BACTERIA: POLYSACCHARIDES: BIO-EMULSIFIER AND ANTI-BIOFILM CAPSULE FROM ANTARCTICA

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Unveiling the unusual features of bacteria: polysaccharides: bio-emulsifier and anti-biofilm capsule from antarctica

Angela Casillo, Raffaele D'Amico, Diana Olimpo, Noemi Gallucci, Caterina D'Angelo, Luigi Paduano, Ermenegilda Parrilli, Maria Michela Corsaro

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Polysaccharides associated with the cell surface (capsular polysaccharides, CPSs) play a key role in bacterial physiology and become even more critical in extremophilic microorganisms, such as cold-adapted bacteria. Structurally, these polymers show very intriguing motifs and bioactivities. A frequent feature of the CPSs is the presence of acidic (-COOH) and acetamido (-$NHCOCH_3$) groups attached to their sugar units [1-3].

Psychrobacter sp. TAE2020 is an Antarctic marine bacterium that produces and secretes a protein-polysaccharides complex, named CATASAN [4,5]. The CATASAN complex contains a polysaccharide, a lipopolysaccharide (LPS), and an outer membrane protein named PsyOmp38 [5].

Here, we report the isolation and characterization of CPS from the cells of *Psychrobacter* sp. TAE 2020. The repeating unit is composed of all aminosugars and decorated by a pyruvic acid. Furthermore, we demonstrate that the polysaccharide composing the CATASAN has the same structure of the CPS. The last is endowed with a notable emulsifying activity, and it can interfere with the biofilm formation of *Staphylococcus epidermidis*, a pathogen associated with chronic infections.

Finally, the adhesion capacity of the active CPS from *Psychrobacter* on lipid vesicles has been analysed by SAXS measurements.

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Keynote 17 - Chemistry, Biology & Physics

2025-08-28
11:00 - 11:30
Keynote 17 - Chemistry, Biology & Physics

K17 - CATCHING ENZYMES IN ACTION

Other
Chemistry, Biology & Physics

CATCHING ENZYMES IN ACTION

Ruzzi, V.[a], Antoine-Assor, C.[b], Bigot, D.-J.[c], Dumon, C.[c],

Montanier, C. Y.[c], Bouchoux, A. [c], Cipelletti, L.[a,d], Ramos, L.*[a]

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The propagation mechanisms of enzymes in the substrates they degrade is an interdisciplinary topic of current debate, involving complex diffusion in crowded environments [1], polymer physics and enzymology. Besides, the understanding of the enzymatic degradation of hemicellulose is of utmost importance for a sustainable production of fuels and bioplastics from plant biomass [2].

We investigate the enzymatic degradation of solutions and gels of arabinoxylan (AX), one of the most abundant polysaccharides of plant hemicellulose, by means of an original optical setup (see Fig. 1) which combines Fluorescence Imaging and Photon Correlation Imaging (PCI), a multispeckle Dynamic Light Scattering technique allowing one to probe the spatio-temporal heterogeneous dynamics of colloidal and polymer systems [3]. Thanks to this setup, the time-evolution of the spatial distribution of the fluorescently-labelled enzyme and the microscopic dynamics of the polymer matrix undergoing degradation are measured simultaneously. In this talk, we will present our innovative technique and our first experimental results. We measure a diffusive degradation front (Fig. 1D), which slows down with increasing AX concentration and is independent of whether the sample is a liquid or a gel. Intriguingly, we find that the enzyme propagation is not influenced by the polymer concentration, thus suggesting that the speed of degradation is mostly determined by the hydrolysis kinetics, set by the enzyme/AX molar ratio. These observations indicate that, in the experimental conditions investigated here, the limiting step is the enzymatic degradation and not the propagation of the enzyme in the polymer network.

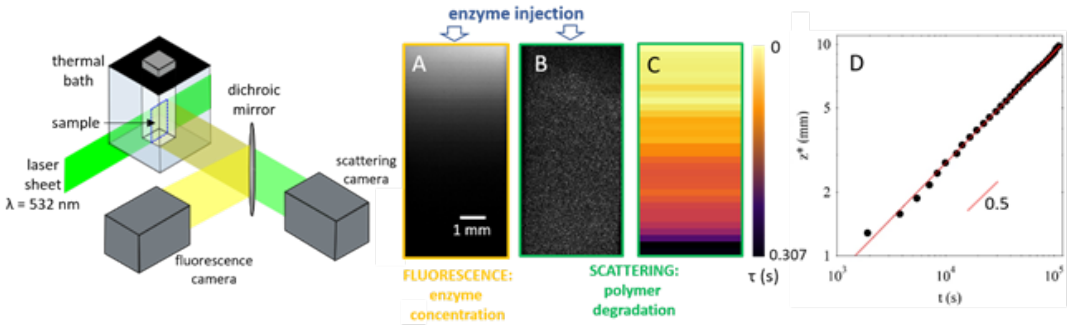

Figure 1. Left Panel: Fluorescence-PCI setup. Right panel: outputs of a degradation experiment: (A) fluorescence image; (B) speckle pattern of scattered light; (C) Dynamic activity map (DAM) of relaxation times two hours after enzyme injection: darker regions refer to non-degraded parts of the sample, while bright regions denote degraded (fluidized) zones of the polymer matrix; (D) Loglog plot of the degradation front advancement

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Keynote 18 - Chemistry, Biology & Physics

2025-08-28
11:00 - 11:30
Keynote 18 - Chemistry, Biology & Physics

K18 - REACTIVE AND THERMORESPONSIVE POLYSACCHARIDE DERIVATIVES FOR CLICK-CHEMISTRY APPROACHES – FROM POLYMER CHEMISTRY TO 3D BIOPRINTING AND NANOGELS

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Reactive and thermoresponsive Polysaccharide Derivatives for Click-Chemistry Approaches – From Polymer Chemistry to 3D-Bioprinting and Nanogels

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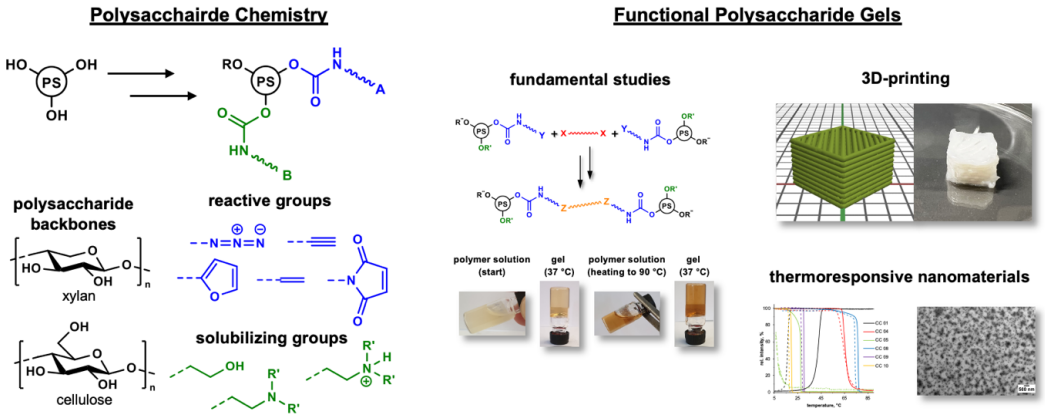
A key challenge in the development of polysaccharide-based materials is the introduction of specific chemical functionalities tailored to target applications. Click-chemistry approaches are highly attractive in this context due to their exceptional selectivity, efficiency, and modularity. This work describes the synthesis of tailored xylan- and cellulose derivatives bearing various reactive click-chemistry groups, and their application in the fabrication of 3D-printable hydrogels and thermoresponsive nanomaterials.

Xylan- and cellulose derivatives were synthesized with reactive click-chemistry functionalities enabling (I) alkyne-azide cycloaddition, (II) Diels-Alder reaction, or (III) thiol-ene coupling. Solubility and thermoresponsive behaviour were further tuned through the incorporation of solubilizing moieties [1]. A modular synthesis approach was employed to ensure broad structural diversity and precise control over the molecular structure, including the degree of substation (DS), with minimal effort.

The reactive polysaccharide derivatives possess great potential for the development of functional biomaterials. In this work, the preparation of functional polysaccharide-based hydro-, organo-, and cryogels by selective covalent crosslinking was studied comprehensively with respect to the different types of click-chemistry reactions [2-4]. Among others, 3D-printable as well as thermoreversible hydrogels were developed. Moreover, functional nanogels were prepared by combining thermoresponsive self-assembling with thiol-ene crosslinking.



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Keynote 19 - Materials & Engineering

2025-08-28
11:00 - 11:30
Keynote 19 - Materials & Engineering

K19 - Chemical Conversion of Cellulose into Polysacharides and Their Applications

Sustainable Materials/Circular Economy
Materials & Engineering

Chemical Conversion of Cellulose into Polysacharides and Their Applications

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Cellulose is the biggest renewable resources in the world. How to convert it efficiently into chemicals is one of most promising fields. It is the key step to produce non-grain bio-based polymers. Cellulose polysaccharides are important oligomers which have number of glucose units. It is difficult to prepare cellulose polysaccharides through chemical method since they are easily to be converted into glucose or by-products. We invent a class of new carbon-based solid catalysts （Figure1）which can selectively cleave cellulose into polysaccharides which have less than ten glucose units [1-3]. The polysaccharides is water soluble and can be converted into various chemicals through fermentation or can be modified into other functional materials.

HEGCS

In-situ functionalization

Carbon Source

Figure 1. Preparation of solid catalyst of hydrixyl enriched carbonaceous carbon spheres (HEGCS)

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Oral

Parallel session 1 - Materials & Engineering

2025-08-25
14:30 - 15:30
Parallel session 1 - Materials & Engineering

O1.1 - TOWARDS SUSTAINABLE PLANT FIBRES FOR THERMOPLASTIC BIOCOMPOSITES: SELECTION AND FRACTIONATION AS KEYS

Sustainable Materials/Circular Economy
Materials & Engineering

Towards sustainable plant fibres for thermoplastic biocomposites: selection and fractionation as keys

Le Moigne, N.*[a], Corn, S.[b], Nour El Dein, A.[a,b,c], Doineau, E.[a], Barbulée, A.[c], Liagre, F.[d], Day, A.[e], Navard, P.[f], Pot, D.[g]

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[c] DEPESTELE, Teillage Vandecandelaere, Bourguébus, France

[d] Agroof SCOP, Anduze, France

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Over the past few decades, plant fibre-reinforced thermoplastic composites have experienced significant growth, particularly in construction (decking & siding) and automotive applications. Nevertheless, the quality of biocomposites and variability in their performance are still technological obstacles for their implementation in industrial applications. This is due to difficulties in tracing the origin of plant fibres and to the successive processing steps, from drying and fractionation process to composite manufacturing, which are not yet well mastered. Indeed, many interdependent parameters govern the final properties of biocomposites, such as biochemical composition, presence of contaminants, (micro)structure, thermal stability, mechanical properties of plant fibres, and the control of their milling/sieving and further processing into composite materials. Furthermore, current environmental concerns are driving the adoption of more sustainable and local practices for the production and use of biomass. In this respect, more sustainable practices as agroforestry, crop optimization through plant breeding programs or even the use of agro-residues are strategic to promote biodiversity and the development of more sustainable biomass for use in material applications. In this context, the development of quality-controlled plant fibres in terms of origin, granulometry, chemical composition and physical properties is essential for their use in biocomposite products. This work investigates the influence of plant species and fractionation steps on the microstructure and mechanical properties of plant fibres reinforced polypropylene (PP) composites manufactured by twin-screw extrusion and injection moulding. The discussion will cover both the fibre and composite scales, with a focus on different European wood species (Figure1),

annual plants and straws to evidence the key roles of species, genotypes and fractionation.

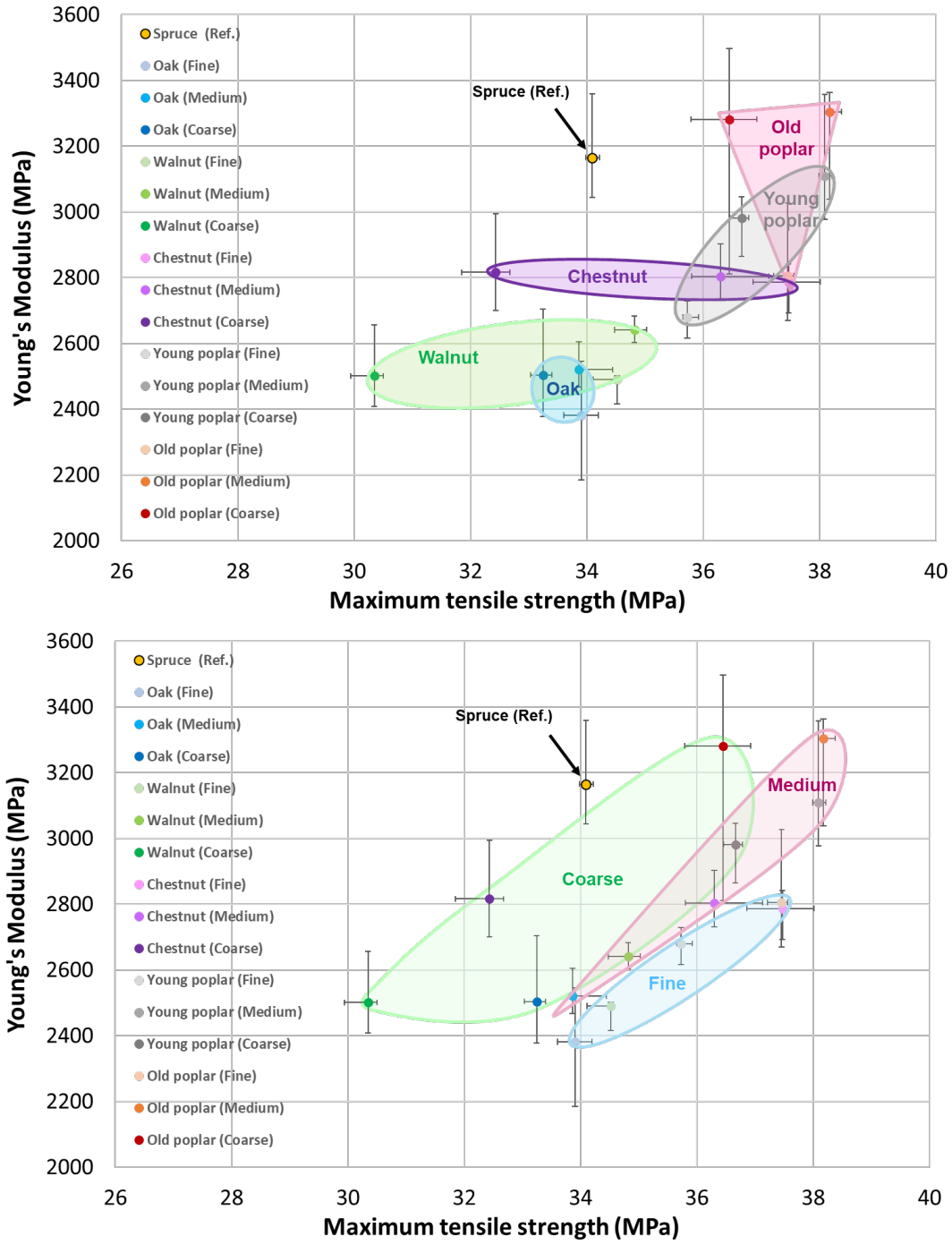

Figure 1. Ashby diagrams for the Young's modulus versus the tensile strength of composites reinforced with various wood species and granulometry

O1.2 - THE NEXT GENERATION OF HIGH-PERFORMANCE FIBERS BASED ON CELLULOSE DERIVATIVES AND WET-SPINNING

Sustainable Materials/Circular Economy
Materials & Engineering

The Next generation of high-performance fibers based on cellulose derivatives and wet-spinning

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In the past decades, considerable efforts have been made to develop sustainable alternatives to fossil-based materials. Among them, sophisticated architectures, such as multilayer structures, composites or fibers, have been designed to obtain the properties usually achieved with petroleum-derived materials. In particular, bio-inspired materials mimicking natural systems have attracted significant attention for their ability to achieve functional properties. Hierarchically ordered fibers found in nature, such as wood or muscle fibrils, exhibit exceptional mechanical and functional properties. Taking inspiration from these materials, fibers containing fillers or serving as reinforcements in composites can provide functional properties such as controlled release or barrier properties, which are essential for biomedical applications, packaging, or membranes.[1,2] However, bio-inspiration in fiber production relies primarily on the structural architecture. With the urgent need to replace petroleum-based materials, both the composition and structure of new sustainable alternatives must take inspiration from Nature.

Here, we present the next generation of sustainable fibers inspired by the composition and architecture of natural systems. We investigate cellulose derivatives as bio-based and biodegradable materials for fibers produced by solution spinning. As one of the most abundant polymers on earth, cellulose and its numerous derivatives have already been used to develop environmentally friendly materials with suitable optical, mechanical and barrier properties.[3] Among them, hydroxypropyl cellulose (HPC) is a low-cost alternative material that is transparent and rigid, with high strength and good barrier properties. Despite these appealing properties, pure HPC fibers have been poorly investigated. Processing bio-based materials into fibers remains a significant challenge. However, this work presents a rapid, efficient and scalable wet-spinning method to produce transparent HPC fibers. HPC fibers present high Young's modulus, tensile strength and degree of crystallinity, which makes them a good alternative to replace petroleum-based fibers, such as polyvinyl alcohol fibers, used in fiber-reinforced composites, packaging materials, sanitary products or cosmetics.

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O1.3 - PREPARATION OF CARBAMATE-MODIFIED CELLULOSE NANOFIBER/ POLYOLEFIN COMPOSITE MATERIAL

Sustainable Materials/Circular Economy
Materials & Engineering

Preparation of Carbamate-Modified Cellulose Nanofiber/ Polyolefin Composite Material

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Cellulose nanofibers (CNFs) have attracted immense attention as reinforcing fillers for polymer composite materials due to their excellent mechanical properties, notably high elastic modulus and remarkable strength. We have previously reported the in situ preparation of CNF-reinforced high-density polyethylene (HDPE) composites under conditions of melt compounding using fibrillation-accelerating agents, such as urea/urea derivatives [1], polyols (glycerol, glucitol) [2], and polymer dispersants [3, 4]. The fibrillation-accelerating agents promoted the plasticization of wood pulp fibers and the dispersion of CNFs in an apolar polymer matrix. The effective fibrilation in the composites was demonstrated to be visualized using confocal laser scanning microscopy, where the length and width of the fiber, aspect ratio, and polydispersity values in the composites were determined [3]. The effects of urea concentration and kneading time on the fibrillation were investigated, indicating that the fiber length and aspect ratio were approximately 40 μm and 40, respectively, under optimal conditions. The maximum Young's modulus was recorded under these conditions, and the recorded value agreed well with the value predicted by the Halpin–Tsai equation. In contrast, excessive kneading and low urea concentration led to fiber fragmentation. Furtheremore, FT-IR and solid-state ^{13}C NMR measurements revealed that urea, used as a fibrillation-accelerating agent, decomposed into ammonia and cyanic acid (HNCO), the latter of which reacted with the hydroxyl groups of cellulose to produce cellulose carbamate efficiently in situ.

$NH_2CONH_2 \rightarrow NH_3 + HNCO$

Cellulose-OH + $HNCO \rightarrow$ Cellulose-$OCONH_2$

Compared with the polyol systems, the carbamate functionalization contributed positively to the composite mechanical properties, probaly due to the strengthening the CNF/polyolefin interphase [2]. Therefore, carbamate-modified CNF (Fig) is a promising filler for the reinforcement of polyolefin. In this presentation, we will discuss the preparation, characterization, and reinforcement effects of carbamate-modified CNFs in polyolefin composites.

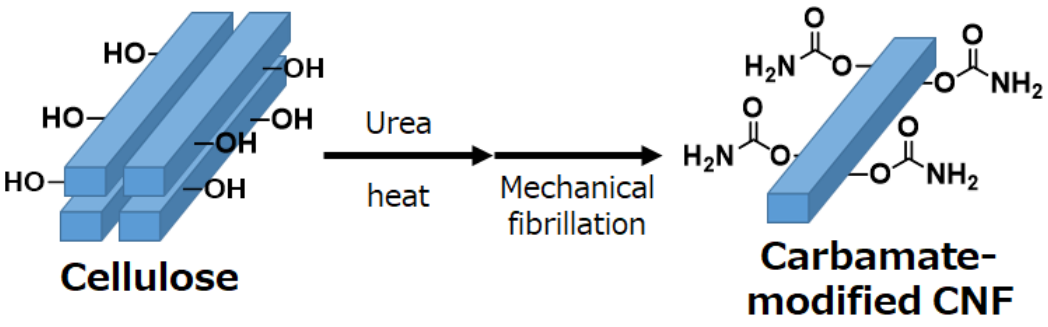

Fig. Preparation of carbamate-modified CNF.

References

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Parallel session 2 - Food & Nutrition

2025-08-25
14:30 - 15:30
Parallel session 2 - Food & Nutrition

O2.1 - Study of the prebiotic properties of wood hemicelluloses oligosaccharides

Dietary Fiber
Food & Nutrition

Study of the prebiotic properties of wood hemicelluloses oligosaccharides

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* PhD Student

Wood hemicelluloses are the second most abundant component in biomass yet remain one of the least studied. As oligosaccharides, they displayed prebiotic properties due to their resemblance to dietary fibers, resistance to acidic conditions, and selective fermentability by gut microbes in mice. Microbiota modulation can positively alter host immunity and health; making wood oligosaccharides a promising option while enabling the pulp industry to valorize byproducts. However, the prebiotic properties of wood hemicelluloses oligosaccharides remain largely unexplored.

This study investigates the prebiotic role of wood hemicelluloses in complex models. As the prebiotic activity of oligosaccharides is linked to their chemical structure, an optimized production process is essential. Oligosaccharides were extracted from softwood chips using the eco-friendly autohydrolysis process controlling the temperature and time, to yield oligosaccharide fractions with different molecular weight ranges. Structural analysis using MALDI ToF and ionic chromatography revealed that the oligosaccharides primarily consist of galactoglucomannans and arabinoxylans to a lesser extent with degree of polymerization from 3 to 17. During production, inevitable byproducts such as organic acids, insoluble lignin, furfural, and hydroxymethylfurfural are generated. Therefore, different purification steps including centrifugation and ultrafiltration are employed to eliminate these contaminants.

The obtained purified oligosaccharides are then studied for their prebiotic effect using *in vitro* models.

Keywords: Hemicellulose, Oligosaccharides, Prebiotic, Microbiota,

O2.2 - IMPACT OF DIETARY FIBRES ON THE GASTROINTESTINAL DIGESTION MECHANISM OF FOOD PROTEINS

Dietary Fiber
Food & Nutrition

Impact of dietary fibRes on THE GASTROINTESTINAL DIGESTION MECHANISM OF FOOD PROTEINS

Díaz-Piñero, L.*[a, b], Correa, Y.[a], Recio, I.[a], Martínez-Sanz, M.[a]

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The growing demand for food and increasing environmental concerns are transforming the global food system. As a result, there is a rising interest in exploring alternative, non-animal protein sources, like seaweeds. However, despite their potential, their use in the food industry is still limited, mainly due to their relatively low protein digestibility, which is linked to the complex polysaccharide structure of their cell walls. Therefore, gaining a deeper understanding on the potential role of seaweed dietary fibres on the gastrointestinal digestion mechanism of proteins is essential for creating strategies to improve protein extraction and digestibility.

This study examined the effect of various polysaccharides commonly found in seaweeds, including agar, alginate, carrageenan, and cellulose, on the digestion of casein, a well-known food protein. All samples underwent *in vitro* gastrointestinal digestion based on the standardized Infogest protocol [1]. The digestion products were then analyzed for mass and protein distribution, rheological properties, microstructure and amino acid composition. Furthermore, the impact of fibres on the nanostructural assembly of the digestion products was studied by advanced small angle X-ray scattering techniques. Our findings show that alginate significantly impairs protein digestibility, followed by carrageenan. In comparison, agar only reduced casein digestibility by up to 17%. Additionally, no significant differences in protein digestibility were observed when varying the agar/casein ratios. Furthermore, the presence of small amounts of solubilised polysaccharides could prevent the assembly of the released peptides into bile salts mixed micelles.

In conclusion, this study highlights the substantial influence of polysaccharides on protein digestion, which could have important implications for the digestibility and bioavailability of proteins derived from seaweeds and other alternative protein sources.

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O2.3 - A Stable Isotope Dilution Approach for Quantification of Total Uronic Acids in Dietary Fiber by LC-MS

Compositional Analysis
Chemistry, Biology & Physics

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Uronic acids, including galacturonic, glucuronic, mannuronic, and guluronic acids, are essential structural components of terrestrial plant and algal cell wall polymers such as pectin, alginate, and xylan, as well as various plant exudates. These polysaccharides are of considerable industrial and scientific interest due to their emulsifying, gel-forming, and thickening properties, which necessitate accurate quantification of their uronic acid contents in order to elucidate structure-property relationships. However, conventional photometric methods, are characterized by limited reproducibility, low sensitivity, and an incomplete understanding of the underlying reaction mechanisms [1, 2].

To address these limitations the present study establishes a robust and sensitive analytical method for the quantification of total uronic acid content in plant-derived materials. The method is based on the thermal degradation of uronic acids in concentrated sulphuric acid, yielding 5-formyl-2-furancarboxylic acid (5FFA) as a characteristic degradation product. After organic extraction, 5FFA is quantitatively analyzed by UHPLC-ESI-MS. To compensate for degradation and extraction losses, an isotopically labelled uronic acid is incorporated as an internal standard, allowing for accurate quantification based on the ratio of the $[M-H]^-$ - singe ion monitoring (SIM) traces of 5FFA and its ^{13}C-labelled analogue.

Method development included the statistical optimization of key reaction parameters, such as extraction solvent, heating time, and temperature, to maximize sensitivity. The method was validated for individual uronic acids and their mixtures and applied to various sample materials, including oligosaccharide standards with defined degrees of polymerization, dietary fibers samples, and plant exudates. In addition, the effect of pre-treatment on different sample matrices was systematically investigated to assess the influence of various modifications such as esterification with methanol and acetic acid as well as methyl ethers.

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Parallel session 3 - Chemistry, Biology & Physics

2025-08-25
14:30 - 15:30
Parallel session 3 - Chemistry, Biology & Physics

O3.1 - ELECTRON PARAMAGNETIC RESONANCE METHODS TO STUDY CONFORMATIONAL DISTRIBUTIONS AND INTERACTIONS OF POLYSACCHARIDE DIETARY FIBERS

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Electron Paramagnetic resonance methods to study conformational distributions and interactions of polysaccharide dietary fibers

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Polysaccharide-based dietary fibers (PDFs) represent an important food component with known health benefits. Besides naturally occurring e.g. in cereals, lentils or beans, PDFs appear as one of the main constituents in plant-based food analogues, such as plant-based milk, yoghurt or meat. Polysaccharide chains are 'sticky' due to repetitive polar groups available for the hydrogen bonds formation, thus making individual chains interact with each other and with other molecules in a mixture. As a result, the internal organization of PDFs mixture with important nutrients, such as vitamins or essential metal ions, would affect the corresponding bioavailability. Unfortunately, the selection of methods that can provide structural information on interactions and conformational ensembles of PDFs in concentrated or semi-diluted samples is quite limited.

In this conference report, we would like to introduce our recently developed Electron Paramagnetic Resonance (EPR) toolkit to study PDFs. Most of the methods we would like to discuss are applicable essentially at any PDFs concentrations, albeit the presented examples will mainly focus on diluted PDFs solutions. EPR can shed light on the partitioning of small paramagnetic or spin-labeled molecules at the loci of PDFs in solution relative to the bulk solvent [1]. Stochastically spin-labeled PDFs can be prepared [2], and their conformational ensembles and interactions with other molecules can be studied using magnetic dipole-dipole interactions between electron spins or between electron and nuclear spins (primarily from ^{1}H or ^{2}H isotops) [3-5]. Changes in the interchain contacts statistics upon interaction with small molecules will be discussed. Besides adapting already existing EPR methods to study PDFs, completely new EPR techniques for quantitative electron-proton distributions analysis were designed, and will be introduced in the context of PDFs research [5,6].

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O3.2 - MRI METHODOLOGIES TO FOLLOW FLUID INGRESS IN PULP-BASED PACKAGING MATERIALS

Chemistry, Biology & Physics

MRI methodologies to follow Fluid ingress in pulp-based packaging materials

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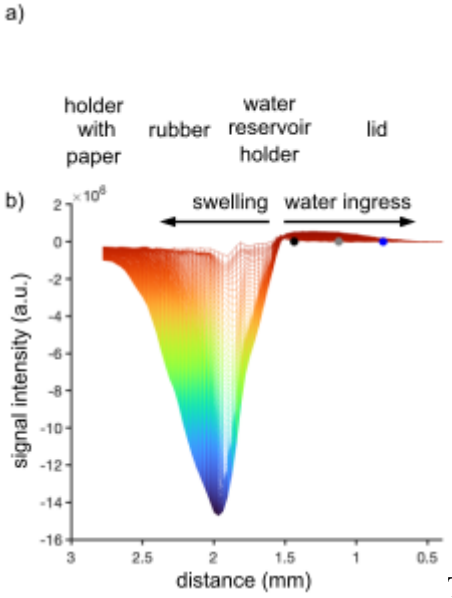
Plastic-based food packages have a huge environmental impact. The recent European Union directive on “single use plastics” pushed forward bio-based solutions for straws and food packages. Cellulose pulp e.g. tissue paper is inherently hydrophilic. Sizing is a common procedure to produce hydrophobized pulp by adding chemicals and thermal activation (see Fig. inset). Food packages are produced using dry-forming or a wet-forming processes; the latter being very energy-consuming. These food packages should withstand water and/or oil for at least a couple of hours. Once the material is wet, it becomes soft and loses its mechanical strength. Optimizing these opaque materials—often only 1 mm thick—demands knowledge about the underlying mechanism of fluid transport through the plane e.g. within the fibers or through pores.



Thin materials require high spatial resolution—tens of microns—which is a challenge for MRI when the fluid ingress occurs within minutes. Drying of ink on paper was studied using a spatial and temporal resolution of 10 µm and 1.3 s[1]. Here we developed a 3D printed rig (see Fig. a) to follow the fluid transport in various sized industrially available pulp-based materials through the plane. Experiments were performed on a Bruker Avance III 300 MHz. ^{1}H profiles in slices spanning the whole paper area were recorded to follow fluid entering through the plane using a 1D multi-slice multi-echo sequence. The spatial and temporal resolution was adjusted dependent on the material—various sized dry-formed packing material, straw paper, and sized and coated cardboards.

In the paper or packaging-making process, pulp fibers align in a preferred orientation impacting the fluid transport mechanism. Hence the rig needed to be designed to avoid any fluid getting in contact with the edges. Our first setup revealed—not surprisingly—that the pulp-based material buckles complicating the measurement over a larger area. This was mitigated through implementing a rubber with an open square into which the water was added (see Fig a). Avoiding water to move between the rubber and the paper, a water reservoir holder fitting into the square of the rubber was added. The lid is then screwed until its edges and the reservoir holder exert pressure on the rubber.

Fig.: Rig setup (a) and normalized ^{1}H profiles stacked with time (b). An example of a sized packaging material in the inset.

Fig b shows that both swelling and water ingress occurred the experiments for a sized packaging material. Swelling indicates transport within the fibres. It takes 80 min for the water to reach the blue point at distance 1 mm (see Fig b). The fluid ingress depends not only on the sizing but also on the forming process as well as the properties of the fluid. Food containing surface-active fluids, breaks the hydrophobic barrier.

Following the fluid ingress through the plane into packaging materials using MRI paves the way for a better understanding of the underlying transport mechanisms crucial for optimizing packaging materials. The gained knowledge is of importance for modelling of fluid transport.

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O3.3 - Absorption of liquid water in paper and wood observed by in-situ X-ray scattering

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Absorption of liquid water in paper and wood observed by in-situ X-ray scattering

Penttilä, P.*[a,b], Ahvenainen, P.[a], Zitting, A [a], Noriega Benitez, E.[a], Liljeström, V.[c], Trevorah, R.[d]

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Absorption of liquid water by cellulosic materials is a fundamental phenomenon with crucial role in absorbent paper products, printing and packaging materials, as well as in various applications and manufacturing steps of wood products. The imbibition of water in such hierarchical porous materials is difficult to study in high detail. Especially, the absorption and transport of water inside cellulosic fibre walls, which swell and change their nanoscale structure with the introduction of water, remains poorly understood.

We utilized time-resolved synchrotron X-ray scattering to observe the imbibition of water in paper and wood, investigating *in situ* the effects of water on the cell or fibre wall nanostructure. The samples were brought into contact with liquid water, after which the water propagation and the associated nanostructural changes were observed with small-angle and wide-angle X-ray scattering (SAXS, WAXS) at a height of 5–10 mm from the water surface.

The scattering data were fitted with models, and the time-dependent changes of the fitting parameters were examined. The results showed similar nanostructural changes with the increasing water content as observed before, including swelling of microfibril bundles and relaxation of lattice strains in the cellulose crystals [1]. The time-dependent behaviour of the paper samples indicated two water fronts with different time constants (Figure 1), assigned to water within fibre walls and between fibres based on literature [2]. The changes in the fibre wall nanostructure were mostly associated with the progress of the faster intra-fibre water, with characteristic time scale of 0.1–3 s. Changes in the wood samples were considerably slower, taking place in the scale of minutes, and more complex to observe due to the heterogeneity of the samples. Nevertheless, in most samples the nanostructural changes happened roughly simultaneously with the absorption of water.

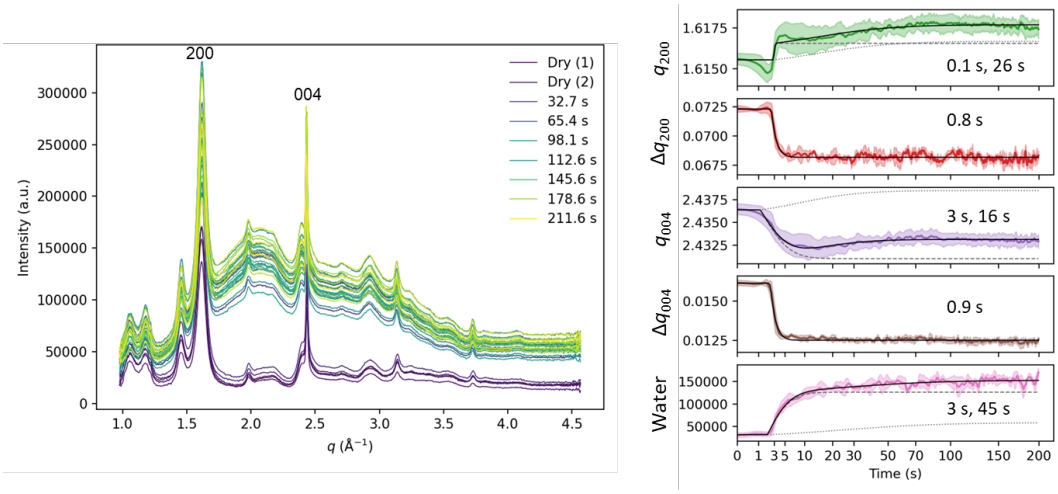

Figure 1. *Left:* WAXS intensities from a wetting experiment with paper. *Right:* Time-dependent changes in the diffraction peak positions (q_{hkl}, Å^{-1}), widths (Δq_{hkl}, Å^{-1}), and the scattering contribution from water, including time constants from fitting a kinetic model *(right)*.

[1] Paajanen, A.; Zitting, A.; Rautkari, L.; Ketoja, J; Penttilä, P., *Nano Lett.* **2022**, *22*, 5143

[2] Ferreira, E.; Drummond, J.; Veiga, A.; Sibellas, A.; Brown, S.; Cranston, E.; Martinez, M., *Carbohydr. Polym.* **2023**, 311, 120785

Parallel session 4 - Biomedical & Well-Being Applications

2025-08-25
14:30 - 15:10
Parallel session 4 - Biomedical & Well-Being Applications

O4.1 - BACTERIAL CELLULOSE AS SUBSTRATE FOR PHOTONIC DEVICES AND WEARABLE SENSORS

Biomedical Devices
Biomedical & Well-being Applications

Bacterial cellulose AS SUBSTRATE FOR photonic DEVICES and WEARABLE SENSORS

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The increased use of synthetic plastic raises concerns about environmental impact. Only from photonic components, the disposal of non-biodegradable plastic waste is estimated at 12,000 million tons by 2050. Biopolymers currently used as synthetic polymer substitutes in photonics applications are predominantly confined to linear optical color responses. Herein we expanded their applications in nonlinear optics by integrating a natural polymer with triplet-triplet annihilation photon upconversion crystals (TTA-UC). Bacterial cellulose (BC) hydrogel served both as a host and template for the crystallization of photon upconversion chromophores whilst a coating with gelatin improved the material's optical transparency. The materials showed an upconversion of 633 nm red light to 443 nm blue light. Notably, components of the construct can be physically disassembled to retrieve 66% of the annihilator, whereas the residual clean BC can be subjected to biodegradation, showcasing the sustainability of the developed photonics device, Figure 1A.[1]

Wearable sweat-sensing platforms represent a transformative advancement in non-invasive, real-time health monitoring, enabling personalized healthcare. For *in vivo* applications, sensor substrates require biocompatibility, safe adhesion, and, preferably, environmental sustainability. We are here introducing BC as a novel electrochemical sensor substrate, leveraging its biocompatibility, comfort, and eco-friendliness. A wearable sweat sensor was fabricated by screen-printing a conductive ink onto BC films. The sensor was further functionalized with alcohol oxidase enzyme to enable reliable alcohol detection in sweat at low concentrations, Figure 1B.[2]

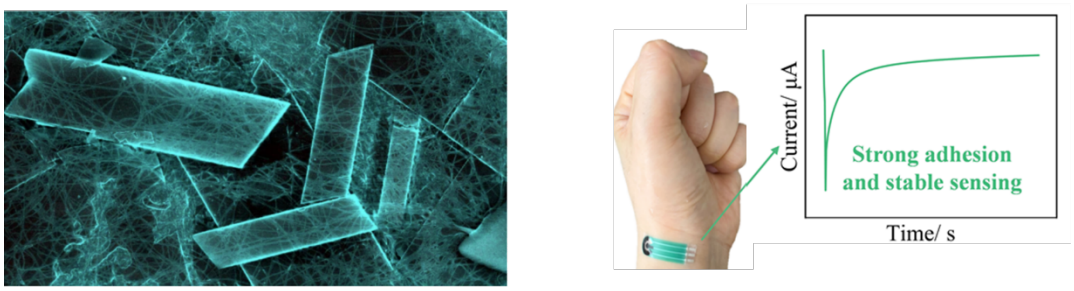

Figure 1. A) Scanning electron microscopy image of TTA-UC crystals embedded in a BC film. B) BC-screen printed electrochemical sensor to measure alcohol concentration in sweat.

[1] Pankaj Bharmoria*, Anna Roig, Kasper Moth-Poulsen* *et al.*, Photon upconversion crystals doped bacterial cellulose composite films as recyclable photonic bioplastics, *Commun Mater* **5**, 200 (2024). https://doi.org/10.1038/s43246-024-00638-6

[2] Xiaohe Wang, Muling Zeng, Mabel Torrens, Pengfei Niu*, César Fernández-Sánchez*, Marti Gich*, Anna Roig*, Eco-friendly Conformal and Self-adhesive Electrochemical Sensors for Sweat Monitoring, *Submitted*.

O4.2 - BACTERIAL CELLULOSE-FUCOPOL COMPOSITE HYDROGEL DRESSINGS FOR ADVANCED WOUND TREATMENT

Biomedical Devices
Biomedical & Well-being Applications

Bacterial Cellulose-FucoPol composite hydrogel dressings for advanced wound treatment

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[d] ITQB NOVA, Instituto de Tecnologia Química e Biológica António Xavier, Universidade Nova de Lisboa, Avenida da República, 2780-157 Oeiras, Portugal

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Chronic wounds present considerable challenges, burdening patients and healthcare systems with substantial costs, especially due to factors such as obesity, diabetes, and aging populations. Effective wound care depends on dressings that prevent infection and facilitate healing, driving research into advanced therapeutic dressings for the development of affordable solutions [1]. Bacterial cellulose (BC), a glucose homopolymer, is highly regarded for wound dressings due to its mechanical strength, nanoporous structure, high water-holding capacity, and biocompatibility [2]. While BC promotes debridement and maintains moisture for wound healing, it lacks essential bio-functional properties, which can be addressed through functionalization with other compounds. FucoPol (FP), a polyanionic, fucose-rich exopolysaccharide, offers wound-healing potential alongside adhesive, photoprotective, and bioactive properties [3,4].

This study combines BC and FP to develop a composite hydrogel designed for wound dressings, leveraging the unique properties of each polymer. BC was impregnated with FP through agitation and gelation using Fe^{3+} (0.26–5 g/L) as a crosslinking agent. Rheological analysis revealed that 2.5 g/L Fe^{3+} was optimal for consolidating the materials and enhancing gel strength compared to BC alone. Increasing FP concentrations (0.5–2.0 wt.%) further improved the composite's mechanical strength, but it reduced its crystallinity index (43-38%), water holding capacity (72-39 g/g) and water retention, compared to BC by itself (crystallinity index: 59%; water holding capacity: 123 g/g). Moreover, the hydrogels demonstrated non-toxicity, with cell viability exceeding 80% in

HaCaT cells (human skin keratinocytes) and NCTC clone L929 (mouse fibroblast) cell lines. Additionally, they supported HaCaT and NCTC clone L929 cell adhesion and enhanced wound recovery, validating their suitability for wound dressing applications.

[1] Man, E.; Hoskins, C., Eur. J. Pharm. Sci. **2020**, 149, 105360.

[2] Horue, M.; Silva, J. M.; Berti, I. R.; Brandão, L. R.; Barud, H. d. S.; Castro, G. R., Pharmaceutics **2023**, 15, 424.

[3] Reis, P.; Pereira, C.; Batista, M.; Sevrin, C.; Grandfils, C.; Marques, A.; Fortunato, E.; Gaspar, F.; Matias, A.; Freitas, F.; Reis, M., Int. J. Biol. Macromol. **2020**, 163, 959–969.

[4] Guerreiro, B. M.; Freitas, F.; Lima, J. C.; Silva, J. C.; Reis, M. A. M., Carbohydr. Polym. **2021**, 259, 117761.

Parallel session 5 - Materials & Engineering

2025-08-25
14:30 - 15:30
Parallel session 5 - Materials & Engineering

O5.1 - DIGITALIZING SEPARATION SCIENCE BY ELECTRONICALLY TUNABLE CELLULOSE-BASED MEMBRANES

Nanostructured Materials
Materials & Engineering

Digitalizing separation science by electronically tunable cellulose-based membranes

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Membrane filtration is the most common separation technology. It is an ancient technique, and although there have been gradual refinements, the basic principles have remained the same for centuries: a passive membrane with a porosity designed for a specific process. Integrating membrane filtration with digital infrastructure – a digitalization of separation science - can take separation technology into a new era with more versatility and adaptability. This transition requires electronically tunable membranes and a few attempts have focused mainly on small molecules or gas permeation. However, no technology has shown promise for this transition until now. Over the last few years, we have developed electrochemically-driven, shape-morphing membranes by combining cellulose nanofibril and conducting nanoparticles such as carbon nanotubes or sheet-like MXenes. Electrochemically osmotic (ECO) actuators enable electrochemical control over a uniaxial out-of-plane swelling up to several hundred percent expansion.[1,2] In this talk, we will share the principles of ECO actuators and demonstrate their unique properties, which are ideal for developing electronically tunable membranes. We will share our demonstration of the world's first electronically tunable membrane with high precision for larger polymers and particles. ECO actuator membranes offer a unique opportunity for digitalized, high-precision, adaptive separation of the future.

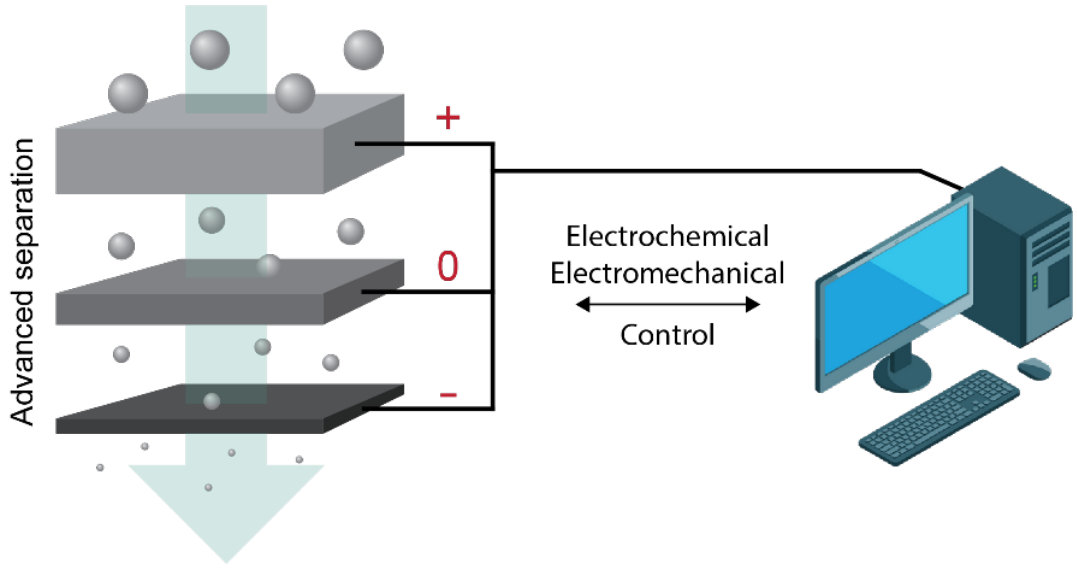

Figure 1. Electronically tunable membranes can digitalize separation science towards advanced

adaptive separation.

[1] Benselfelt, T. et al. “Electrochemically controlled hydrogels with electrotunable permeability and uniaxial actuation.” Advanced Materials 35.45 (2023): 2303255.

[2] Li, L. et al. “Ultrastrong ionotronic films showing electrochemical osmotic actuation.” Advanced Materials 35.45 (2023): 2301163.

O5.2 - STRONG OR WEAK: WHO TAILORS THE MICROSTRUCTURAL PROPERTIES OF CELLULOSE AEROGEL BEADS?

Nanostructured Materials
Materials & Engineering

Strong or weak: who tailors the microstructural properties of cellulose aerogel beads?

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Cellulose aerogels are versatile materials having interconnected nanofibrillar network, low density and high porosity. They can be produced in different forms by shaping the solution to monoliths, sheets, beads and 3D printed complex structures. They can be effectively used for various applications when the physical properties can be tuned to adapt the demands. As these materials have meso- and macropores, tuning the pore volume can be done during gel network formation. Tailoring the properties of cellulose aerogel beads will be discussed in the presentation. Cellulose aerogel beads were commonly prepared by adding anti-solvents in the coagulation bath. Anti-solvents can generate the aggregated cellulose nano-network which leads to the formation of complete wet-gel body. One of the methods of gel structure formation can be developed by reversing the pH value, i.e., pH-induced gelation [1]. Cellulose can be dissolved in NaOH-water medium in the presence of additives such as urea [2]. The addition of acids in the coagulation bath can induce the gel-structure formation. We have been investigating the use of weak organic acids as coagulants to tailor the properties of cellulose aerogel beads [3]. Three weak acids, acetic acid, lactic acid, and citric acid, and a strong acid, hydrochloric acid, were chosen as coagulation baths. The production of aerogel beads by conventional dropping technique was studied and optimized for each acid. The produced cellulose aerogels were characterized by nitrogen adsorption-desorption isotherm, BJH pore data analyses, density analyses, IR spectroscopy, scanning electron microscopy, and X-ray powder diffractometry, and their properties were compared. In common, all the aerogel beads showed interconnected nanofibrillar network. The pore size distribution was highly influenced by the acids employed for regeneration. High concentration of weak acids contributed to low shrinkage, high specific surface area and high pore volume. In conclusion, this study showed an alternate path way to tailor the properties of cellulose aerogel beads.

[1] Ganesan, K., Budtova, T., Ratke, L., Gurikov, P., Baudron, V., Preibisch, I., Niemeyer, P., Smirnova, I., Milow, B., *Materials*, **2018**, 11, 2144.

[2] Budtova T., and Navard P., *Cellulose*, **2015**, 23(1), 5-55.

[3] Costa D., Milow B., and Ganesan K., *Chem. Eur. J.*, **2024**, 30(51), e202401794.

O5.3 - Insights into the Colloidal Deacetylation of Chitin Nanocrystals

Nanostructured Materials
Materials & Engineering

Insights into the colloidal deacetylation of chitin nanocrystals to produce chitosan nanocrystals

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[b]Department of Physics, Freie Universitat Berlin, Germany

The valorization of crustaceous chitin typically follows two primary pathways: (1) deacetylation to produce macromolecular chitosan and (2) acid-catalyzed depolymerization to yield chitin nanocrystals (ChNCs).[1] Recently, nanoscale deacetylation of ChNCs has been achieved, enabling a degree of deacetylation (DDA) exceeding 90% for the first time.[2] These novel chitosan nanocrystals (ChsNCs) exhibit superior performance compared to ChNCs and even cellulose nanocrystals (CNCs) in applications such as heterogeneous catalysis, drug delivery hydrogels, and adhesive materials.[3]

Despite these advancements, the inherent nanostructure of ChsNCs in aqueous suspension and the underlying mechanism of their deacetylation remain poorly understood. In this presentation, I will discuss recent investigations into the behavior and architecture of these modified nanocrystals. Using Cryo-EM and electron diffraction, we have visualized the internal α-chitin core. Additionally, s-SNOM (scattering-type scanning near-field optical microscopy) has been employed to elucidate the initiation points of deacetylation within ChNC colloids and to determine the nanoscale distribution of chitosan chains. Finally, by combining nanoscale imaging techniques with bulk characterization methods, we propose a detailed rationale for the deacetylation mechanism of ChNCs and present a model for the spatial distribution of chitosan chains on ChsNCs.

(1) Jin, T.; Liu, T.; Lam, E.; Moores, A. Chitin and chitosan on the nanoscale. *Nanoscale Horiz.* **2021**, *6* (7), 505-542, 10.1039/D0NH00696C. DOI: 10.1039/D0NH00696C.

(2) Jin, T.; Kurdyla, D.; Hrapovic, S.; Leung, A. C. W.; Régnier, S.; Liu, Y.; Moores, A.; Lam, E. Carboxylated Chitosan Nanocrystals: A Synthetic Route and Application as Superior Support for Gold-Catalyzed Reactions. *Biomacromolecules* **2020**, *21* (6), 2236-2245. DOI: 10.1021/acs.biomac.0c00201.

(3) Jin, T.; Liu, T.; Jiang, S.; Kurdyla, D.; Klein, B. A.; Michaelis, V. K.; Lam, E.; Li, J.; Moores, A. Chitosan nanocrystals synthesis via aging and application towards alginate hydrogels for sustainable drug release. *Green Chem.* **2021**, *23* (17), 6527-6537, 10.1039/D1GC01611C. DOI: 10.1039/D1GC01611C.

Paralell session 6 - Materials & Engineering

2025-08-25
16:00 - 17:40
Paralell session 6 - Materials & Engineering

O6.1 - FROM MICROBIAL POLYMERS TO MATERIAL INNOVATION: CHARACTERIZING EXTRACELLULAR POLYMERIC SUBSTANCES IN LIVING BUILDING MATERIALS

Sustainable Materials/Circular Economy
Materials & Engineering

From Microbial Polymers to Material Innovation: Characterizing Extracellular polymeric substances in Living Building Materials

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The construction industry—particularly cement manufacturing—is a major contributor to global CO_2 emissions, highlighting the urgent need for sustainable alternatives. Living Building Materials (LBM), which integrate photosynthetic microorganisms such as cyanobacteria, offer a promising bio-based approach. These organisms contribute to material stabilization through biologically induced mineralization and the production of extracellular polymeric substances (EPS), including structurally complex exopolysaccharides.

Despite their critical role in bio-cementation and structural integrity, the chemical structure and functional properties of cyanobacterial EPS remain poorly understood. In this study, we applied a multi-analytical approach to characterize EPS from both a unicellular and a filamentous cyanobacterial strain. Photometric assays determined the carbohydrate and protein content of crude EPS extracts. For detailed analysis of the polysaccharide fraction, HPLC-DAD was employed to analyze monosaccharide composition, while LC-MS/MS of partially hydrolyzed oligosaccharides provided structural fingerprints indicative of linkage patterns and functional motifs.

To enable a deeper understanding of the functional role of EPS in LBM, the obtained molecular data will serve as a basis for establishing structure–property relationships between EPS composition and material performance. By correlating specific structural features—such as polymer and monosaccharide composition, branching patterns, and functional groups—with material properties like tensile, compressive and bending strength, we aim to identify key determinants of bio-cementation efficiency. These insights will support both the optimization of microbial material systems and the informed selection of cyanobacterial strains with desirable properties for construction applications.

Our findings contribute to a deeper understanding of microbial material formation and open new avenues for the development of tunable, and climate-resilient building materials.

O6.2 - Bioactive cellulose foams made from laccase mediated polydopamine and ferulic acid grafting

Sustainable Materials/Circular Economy
Materials & Engineering

BIOACTIVE CELLULOSE FOAMS MADE FROM LACCASE MEDIATED POLYDOPAMINE AND FERULIC ACID GRAFTING

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Low density foams made from cellulose stands as an interesting product to replace traditional foams made form polystyrene, polyethylene, polyurethane etc., which are non-biodegradable but also derived from non-renewable sources. Furthermore, multifunctional materials which incorporate chemical, physical or biological functionalities on the materials enhance the overall properties of the material itself. By utilizing this as a combination, we are in this study aiming to create a multifunctional cellulose foam which has enhanced bioactive properties with high potential in a wide range of niche applications such as the pharmaceutical and food industry.

Laccase mediated grafting works mainly on substrates containing phenolic hydroxyl groups. To impart these groups onto the bleached cellulose fibers, a coating of polydopamine was added on the cellulose surface followed by the grafting of ferulic acid using laccase as a biocatalyst. Both the reactions were optimized for the substrate ratio, time, enzyme load, pH etc., offering the highest functionalization. The best samples were then utilized to create cellulose foams by inducing air into a system containing pulp, additives and surfactants. The properties of the final foams were also correlated to the grafting process. This method gives way to a low-waste design to produce high value-added low density and porous materials.

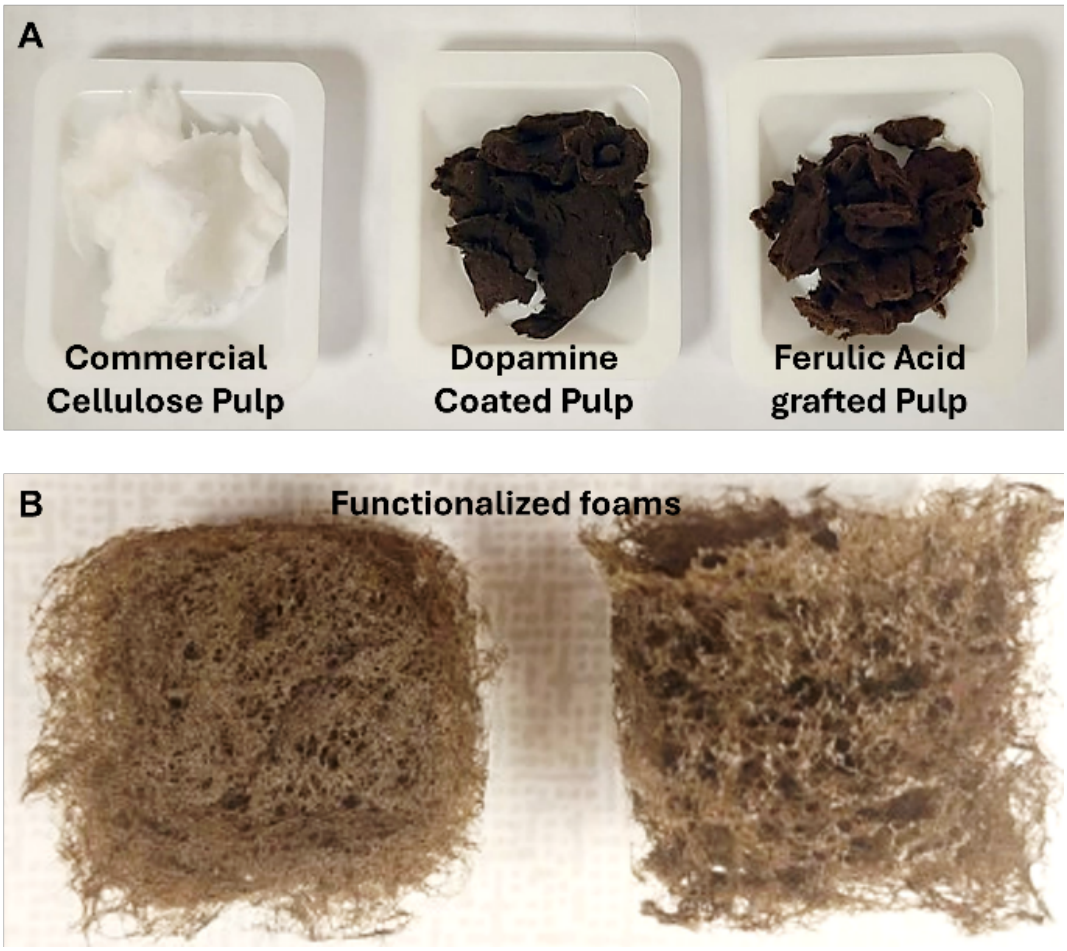

Figure 1. A: Appearance of the pulp samples before and after treatments, B: the top and side view of the foams

O6.3 - SUSTAINABLE TECHNOLOGY FOR FABRICATION OF HYDROPHOBIC CELLULOSE FOAM

Sustainable Materials/Circular Economy
Materials & Engineering

Sustainable Technology for Fabrication of Hydrophobic Cellulose Foam

Rana Alimohammadzadeh*[a], Praven Kamalanathan[b], Tianyu Guo[b], Orlando Rojas[b], and Armando Cordova[a].

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[b] Bioproduct Institute, University of British Columbia, BC Canada

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Bio-based lightweight materials have gained significant attention from both academia and industry.[1] While some bio-based lightweight materials have been successfully developed, many are not fully bio-based, often requiring organic solvents and complex fabrication processes. Here, we present a green and feasible strategy for fabricating hydrophobic bio-based foams with enhanced mechanical strength. Cellulose has emerged as a promising resource for advancing the transition from a fossil-based economy to a bioeconomy. However, its susceptibility to humidity and water absorption significantly affects its properties. We demonstrate a one-pot reaction to design a hydrophobic cellulose foam with high mechanical performance. The fabrication process involves preparing an organocatalytic aqueous formulation (OAF), initiated by alkoxysilane polymerization, and subsequently applying this OAF during foam production.[2] The combination of OAF, a sustainable polyelectrolyte, and cellulose pulp resulted in a hydrophobic foam with significantly improved strength (E-modulus increased from 2.75 to 22 kPa).[3] Elemental mapping images confirm the uniform distribution of OAF on the lignocellulosic fibers of the foam. The resulting bio-based hydrophobic foam shows great potential for decontamination applications, such as oil removal from water. All ingredients are non-toxic and readily available in large quantities, ensuring cost-effective scalability.

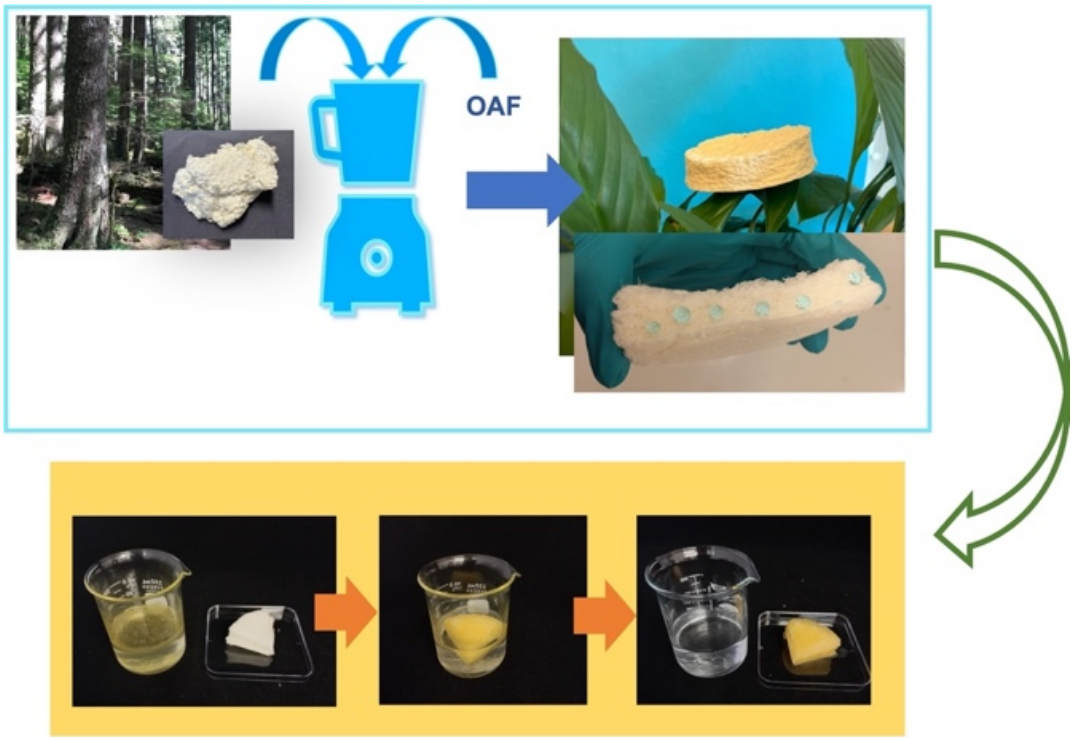

Figure 1. Hydrophobic cellulose foam for oil removal from water

[1] Klemm, D.; Kramer, F.; Moritz, S.; Lindström, T.; Ankerfors, M.; Gray, D.; Dorris, A. *Angewandte Chemie - International Edition* **2011**, *50* (24), 5438–5466.

[2] Alimohammadzadeh, R. ; Ferreira, d. ; Hamdouche, Z.H. ; Mõistlik, T. Córdova, A. *Green Chemistry* **2025**, **https://doi.org/10.1039/D4GC06342B**

[3] Cordova, A.; Alimohammadzadeh, R. US Patent application.

O6.4 - BIODESIGN OF PHOTOSYNTHETIC BIOHYBRIDS THROUGH NANOCELLULOSE WATER INTERACTIONS

Sustainable Materials/Circular Economy
Materials & Engineering

Biodesign of Photosynthetic Biohybrids through Nanocellulose Water Interactions

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[b] Division of Systems Biology, KTH Royal Institute of Technology, Sweden

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Biodesign is a field across multiple disciplines that explores the integration of living organisms and biological processes into "living materials" with novel functions, leveraging the unique properties of biological systems. Photosynthetic microorganisms such as cyanobacteria and microalgae convert carbon dioxide into organic compounds and biomass, and can be further engineered to produce a broad range of industrially relevant molecules with a lower intrinsic carbon footprint than conventional petroleum-based alternatives [1]. In this context, nanocellulose emerges as a versatile material platform due to its physical and chemical versatility and biocompatibility [2]. However, bridging the fundamental understanding of nanocellulose–water interactions with the design of functional and living materials remains a challenge [3].

The research described in this contribution takes on board this challenge by leveraging the nanocellulose-water interactions to produce tailored cellulose nanofiber matrices for the immobilization of cyanobacteria. Using osmotic (de)hydration [4], the structure-property relationship between the matrix and the microbial growth has been evaluated in terms of the nanofibers characteristics, porosity and gas-fluid transport. The photosynthetic biohybrids have excellent cell viability over 30 days, accompanied by mechanical stability under wet conditions. This presentation offers a new perspective on using nanocellulose-water interactions to enhance and tailor material performance towards a carbon-neutral society.

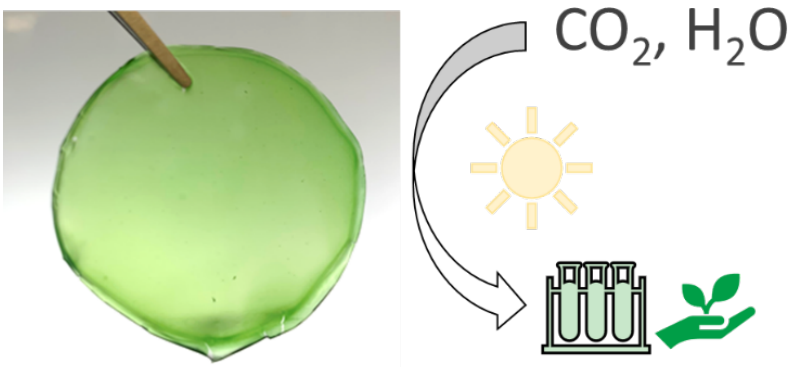

Figure 1. A photosynthetic biohybrid containing Synechocystis PCC 6803 (diameter 4.9 cm)

[1] I.S. Yunus, J. Anfelt, E. Sporre, R. Miao, E. P. Hudson and P.R. Jones; Metabolic Engineering 72 (2022) 14-23.

[2] V. Rissanen, S. Vajravel, S. Kosourov, S. Arola, E. Kontturi, Y. Allahverdiyeva and T. Tammelin; Green Chemistry (2021), 23, 3715.

[3] L. Solhi, V. Guccini, K. Heise, I. Solala, E. Niinivaara, W. Xu, K. Mihhels, M. Kröger, Z. Meng, J. Wohlert, H. Tao, E. D. Cranston, E. Kontturi; Chemical Review (2023) 123, 1925-2015.

[4] V. Guccini, J. Phiri, J. Trifol, V. Rissanen, S. M. Mousavi, J. Vapaavuori, T. Tammelin, T. Maloney and E. Kontturi; ACS Applied Polymer Materials. 2022, 4, 1, 24–28.

O6.5 - 'Food-compatible' Deep Eutectic Solvents for Enhanced Sugarcane Trash Fractionation and Valorisation

Sustainable Materials/Circular Economy
Materials & Engineering

'Food-compatible' Deep eutectic solventsfor enhanced sugarcane trash fractionation and valorisation

Yujie Mao*[a], Dwi Ajias Pramasari[a], Eleanor Binner[a]

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The development of second-generation biorefinery addresses the challenges of lignocellulosic biomass valorisation, enabling the full utilisation of biomass components (i.e. cellulose, hemicellulose and lignin) while minimising the waste. To achieve this, one of the crucial steps in biorefinery processes is the biomass fractionation. Industrial processes and much of the research literature primarily focus on lignin separation and cellulose preservation. This is because the high lignin content and the recalcitrant structure of lignocellulosic biomass reduce the production yield of biofuel and biochemical from polysaccharides. Common delignification methods involve strong alkali (as in commercial Kraft process), acids and organic solvents under hydrothermal temperature/pressure. Pitfalls associated with these techniques are poor environmental and sustainability credentials, as well as the degradation of the lignin into low-value fragments, hindering its further upgrading.[1] Additionally, they offer low hemicellulose preservation, as hemicellulose undergoes continuous degradation in the extraction solvent and becomes less recoverable due to reduced molecular weight.[2]

To address the abovementioned technical challenges and to fulfil the EU's Circular Economy Concept, this research aims to develop a sustainable and cost-effective approach for biomass fractionation and the valorisation of all three key components (Figure 1). To ensure environmental sustainability and efficient lignin extraction, we propose the use of low cost, food-compatible and highly lignin-soluble Deep Eutectic Solvents (DES) as an alternative to conventional extraction methods.[3] To best preserve the hemicellulose fraction, which is more chemically and thermally sensitive than cellulose and lignin, we integrated a biorefinery approach to recover the hemicellulose under milder conditions (step 1) prior to the lignin extraction (step 2). Step 1 will be optimised based on xylose/xylooligosacchride yields in the hydrolysate by evaluating the effect of extraction time and DES concentration. Effectiveness of step 2 will be assessed by lignin yield and purity. Finally, both the lignin and cellulose fraction will be characterised by their physiochemical properties to explore their distinct potential applications. Detailed experimental results will be presented at the conference.

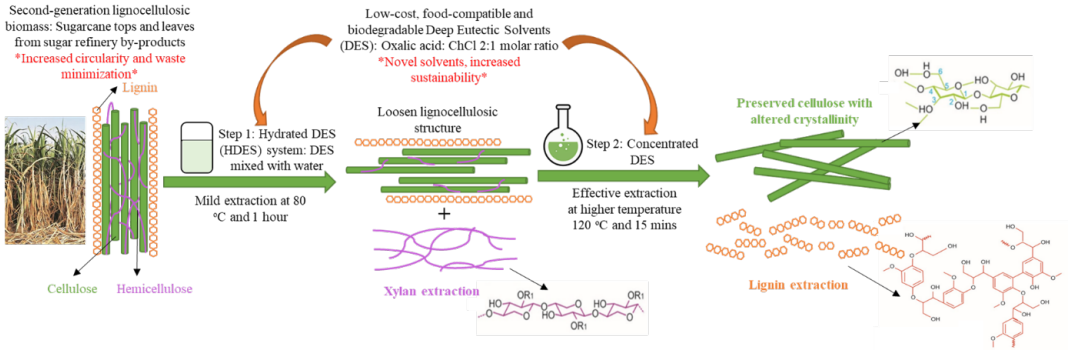

Figure 1. Two step biomass fractionation using 'food-compatible' Deep Eutectic Solvents.

Reference: [1] Biotechnol. Biofuels, 2021, 14(1), 102. **[2]** Ind Crops Prod., 2022, 187, 115335. **[3]** Bioresour. Technol., 2023, 372, 128680

Paralell session 7 - Food & Nutrition

2025-08-25
16:00 - 17:20
Paralell session 7 - Food & Nutrition

O7.1 - THE ANTIOXIDANT ACTIVITY OF POLYSACCHARIDES - FACTS AND MITHS

Dietary Fiber
Food & Nutrition

The antioxidant activity of polysaccharides - FACTS AND MITHS

Fernandes, P.A.R. and Coimbra, M.A.*

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Over the last years, polysaccharides have been linked to antioxidant effects using both in vitro chemical and biological models. The reported structures, claimed to act as antioxidants, comprise chitosan, pectic polysaccharides, glucans, mannoproteins, alginates, fucoidans, and many others of all type of biological sources. However, questions still exist such as: Are polysaccharides relevant antioxidants? What is the impact of food processing on polysaccharides antioxidant activity? Are there contaminant effects by antioxidants such as phenolic compounds, vitamins (E and C) and carotenoids? Can the isolation of polysaccharides promote changes in their antioxidant activity?

The structural features linked to the antioxidant action include the polysaccharide charge, molecular weight, and the occurrence of non-carbohydrate substituents. The establishment of structure/function relationships can be, however, biased by secondary phenomena that tailor polysaccharides behaviour in antioxidant systems. Despite falling in the concept of antioxidants, the role of polysaccharides must be well defined according with the matrices where they are involved.

Based on the paper published in 2023 entitled “The antioxidant activity of polysaccharides: a structure-function relationship overview” [1], the basic concepts of polysaccharides chemistry are proposed to be related with the current claim of carbohydrates as antioxidants, highlighting how the fine structure and properties of polysaccharides can render them antioxidants.

Acknowledgments: This work was funded by project VIIAFOOD, from PRR, and project “cLabel+ 46080 throught SI I&DT – Programas Mobilizadores”, POCI-01-0247-FEDER-046080 and LISBOA-01-0247-FEDER-046080. Authors acknowledge the FCT financial support through UID/50006 LAQV/REQUIMTE within the PT2020 Partnership Agreement.

1. P.A.R. Fernandes, M.A. Coimbra, Carbohydr. Polym., 314, (2023) 120965.

O7.2 - Engineering of Arabinoxylan Fibres Towards Prebiotic Hydrogels Using Hydrolases and Oxidative Enzymes

Dietary Fiber
Food & Nutrition

Engineering of Arabinoxylan Fibres Towards Prebiotic Hydrogels Using Hydrolases and Oxidative Enzymes

Rämgård Carl[1], Mckee Lauren[1] Vilaplana Francisco[1]

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Food losses and waste is a hot topic in the current environmental debate. From the agricultural industry, one major source of food waste is cereal bran[1], which consists of the fibrous, outer layer that encapsulates the edible seed of most grain varieties. The bran is mainly composed of polysaccharides, primarily arabinoxylans[2]. These polysaccharides are heavily substituted and in turn are also covalently linked by phenolics, mainly ferulic acid, which is the most commonly abundant phenolic in most cereal grains [3]. These polysaccharides, or dietary fibres have proven to have significant nutritional health benefits in prebiotic gut fermentation and contributing functional properties to food products [4, 5], both based on their structure but also the phenolic substitutions. These properties make arabinoxylans an essential biopolymer for valorisation of a common by product in one of the world's biggest and most crucial industries. The presence of the phenolic substitutions enables the crosslinking of the polymers into stable hydrogels using oxidative laccase enzymes [6].

These hydrogels are especially interesting in vast array of applications, such as food additives in the form of nutrition or stabiliser, prebiotic applications for the human gastrointestinal tract flora and novel drug delivery system for the gastrointestinal tract. Through enzymatic engineering, using selective hydrolases we have proven that cereal arabinoxylans from wheat and rye bran can be modified to tailor their hierarchical assembly in hydrogels and improve their functional properties towards their potential valorisation as food ingredients.

Figure 1 **Figure 1 Removal of arabinose on arabinoxylan using arabinofuranosidases and crosslinking of polymers using laccases**

1. Cui, S.W., Y. Wu, and H. Ding, *5 - The range of dietary fibre ingredients and a comparison of their technical functionality*, in *Fibre-Rich and Wholegrain Foods*, J.A. Delcour and K. Poutanen, Editors. 2013, Woodhead Publishing. p. 96-119.

2. Chanliaud, E., L. Saulnier, and J.F. Thibault, *Alkaline extraction and characterisation of heteroxylans from maize bran.* Journal of Cereal Science, 1995. **21**(2): p. 195-203.

3. Boz, H., *Ferulic Acid in Cereals - a Review.* Czech Journal of Food Sciences, 2014. **33**: p. 01-07.

4. Amritpal, K., et al., *Isolation and characterization of arabinoxylans from wheat bran and study of their contribution to wheat flour dough rheology.* Carbohydrate Polymers, 2019. **221**: p. 166-173.

5. Rosicka-Kaczmarek, J., et al., *The influence of arabinoxylans on the quality of grain industry products.* European Food Research and Technology, 2016. **242**(3): p. 295-303.

6. Yilmaz-Turan, S., et al., *Revealing the mechanisms of hydrogel formation by laccase crosslinking and regeneration of feruloylated arabinoxylan from wheat bran.* Food Hydrocolloids, 2022. **128**: p. 107575.

O7.3 - NANOSTRUCTURAL MODIFICATIONS OF BACTERIAL CELLULOSE INDUCED BY ALGAL POLYSACCHARIDES

Food & Nutrition

Nanostructural Modifications of Bacterial Cellulose Induced by Algal Polysaccharides

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The demand for sustainable materials has intensified research into marine resources, in particular macroalgae. Algal cell walls are rich in diverse polysaccharides (cellulose and non-cellulosic such as alginates, fucoidan, laminarin, carragenan, agar, etc.) with unique functional properties. However, algae cell wall complex architecture remains poorly understood. A mechanistic understanding of algae polysaccharide interactions is key for designing biomaterials with tailored technological properties and, to optimise our use of this marine biomass. However, systematic studies on algal polysaccharide assemble are lacking behind compared to land plants. Mimicking plant cell wall architectures using bacterial cellulose hydrogels has previously provided insights on polysacccharide interactions in real systems [1]. Our approach extends this concept to algae, here we have successfully synthesized a range of bacterial cellulose-based biomimetics incorporating a range of algal polysaccharides. This biomimetic approach enabled us to study cellulose/polysaccharide interactions at multiple length scales, integrating advanced structural characterization (WAXS-SAXS, XRD, FTIR), rheology, and chemical analysis. Unlike previous studies focusing on composition and bulk properties, our work aims to reveal the molecular and supramolecular interactions determining algae cell wall structure and material properties. Small angle X-ray scattering (SAXS) experiments conducted at ALBA (Spain) revealed that different polysaccharides induced distinct modifications in the nanoscale organization of cellulose nanofibrils, influencing both structural arrangement and density. WAXS and XRD data indicated that while some polysaccharides affect cellulose crystallinity, others have minimal impact. These structural differences were correlated with mechanical and rheological properties. Our results i) enhance our knowledge about assembly of algal cell walls and ii) provide a foundation for engineering tailored algal polysaccharide networks, with potential applications in food, pharmaceuticals, and sustainable

biobased packaging.

[1] Lopez-Sanchez, P.; Martinez-Sanz, M.; Bonilla, M.R.; Wang, D. ; Gilbert, E.P.; Stokes, J.R. ; Gidley, M.J. ; *Carbohydr. Polym*. **2020**,*162*, 71-81

O7.4 - Influence of ph-shift-based protein extraction on the properties of ulvan produced from Ulva fenestrata with a biorefinery approach

Dietary Fiber
Food & Nutrition

Influence of ph-shift-based protein extraction on the properties of ulvan produced from *ulva fenestrata* with a BIOREFINERY approach

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Ulvan is a polysaccharide found in the cell wall of the green algae *Ulva*, of which represents up to 36% of the dry biomass. It is mainly constituted by repeating →4)-β-D-GlcA-(1→4)-α-L-Rha3S-(1→ and →4)-β-L-IdoA-(1→4)-α-L-Rha3S-(1→ disaccharides. Ulvan has potential applications in biomaterial sciences (wound dressing and tissue engineering) and in the food industry.

In addition to ulvan, *Ulva* is rich in proteins, which constitute up to 25% of the dry biomass. They have essential amino acid and digestibility profiles relevant for human nutrition. The alkaline extraction and isoelectric precipitation of proteins, is a promising strategy, commonly called “pH-shift”, for the exploitation of *Ulva* as protein source.

The production of multiple fractions from the same raw material in cascade manner would increase the revenues of *Ulva* exploitation. In addition, subsequent processes might benefit from tissue disruption determined by previous steps. The macromolecular properties of ulvan, and hence its applications, are influenced by its extraction conditions. Therefore, harmonization of different cascade steps in biorefining is important.

In the present work, the respective effects of pH-shift and ulvan extraction on polysaccharide and protein quality were investigated in terms of yield, monomer composition, and molecular weight on one hand and in terms of protein yield and secondary structure on the other. Purified ulvan was submitted as well to pH-shift conditions for comparison.

The outlining of processing effect on chemical composition and properties of nutrient and bioactive compounds contributes to increasing the industrial applicability of *Ulva* as ulvan and proteins are among its main bioeconomy opportunities.

Paralell session 8 - Chemistry, Biology & Physics

2025-08-25
16:00 - 17:40
Paralell session 8 - Chemistry, Biology & Physics

O8.1 - Chemical Heterogeneity of Polysaccharides: Chromatographic Characterization

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Chemical heterogeneity of polysacharides: Chromatographic characterization

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IFF has been developing and commercializing novel enzymatically polymerized polysaccharides. The scope for the Designed Enzymatic Biomaterial™ platform technology is to produce sustainable and scalable biomaterials with tailored molecular structure and architecture. For example, such polymers are various glucans, i;e. homopolymers of glucose produced directly from sucrose as a substrate using glycosyltransferase enzymes. These polysaccharides can be optionally further tailored to the application needs by post polymerization derivatization. In this process, the hydroxyl groups of the original macromolecules are substituted with various functional groups, neural or ionic.

The selectivity of the substitution at different molecular and supramolecular levels will depend on reaction conditions and does play a crucial role in optimizing the polymer properties. Consequently, its determination is an important part of the overall polymer design and characterization process. Various spectroscopic techniques, mostly NMR, are the methods of choice in characterizing regioselectivity of substitution at the glucose (monomer) level, and often require full hydrolysis of the polymer chain prior to analysis. But these methods are usually unable to detect other types of substitution selectivity in the polymer, including the distribution of the substituted groups along the polymer chain (chain blockiness), as well as distribution of these groups between different chains (compositional heterogeneity of the polymer).

Such analyses could be done by Interaction Polymer Chromatography (IPC). IPC is comprised of liquid chromatography techniques aimed on separation of polymer chains by various molecular properties different from their size in solution and will allow such analyses of intact polymers [1]. Thus, the approach called gradient elution at critical point of adsorption provides separation of copolymers by chemical composition [2] and chain microstructure [3] independent on chain molar mass. This approach was demonstrated for the characterization of chemical molecular heterogeneity in many synthetic copolymers using reversed-phase (retention determined by hydrophobic substituents) and normal phase (hydrophilic groups) separations [4].

In this presentation, we extend the IPC method to include separations determined by H-bond retention, as well as by ionic interaction with stationary phase (ion-exchange IPC). These novel approaches were applied for the characterization of the chemical composition distribution and chain blockiness in various chemically modified enzymatically polymerized glucans as well as natural polysaccharides. The demonstrated examples include carboxymethylated and cationic polyglucans with various linkage compositions, as well as polyglucan esters and ethers. In the last case, we

demonstrate an example of 2-dimentional chromatography, where H-bond-induced separation by hydroxyl groups is followed by reversed-phase separation by hydrophobic substituents.

[1] Striegel, A.M., *Trends in Anal Chemistry* **2020**, *v. 130*, p. 1

[2] Brun,Y.; Alden, P., *J. of Chrom. A* **2002**, *v. 966*, p.25

[3] Brun, Y.; Foster, P., *J. of Sep Sciences* **2010**, *v.33,* p.2501

[4] Brun, Y.; Rasmussen, C.J., in *Handbooks in Separation Sciences*: *Liquid Chromatography*, *v.1*, p. 275, Elsevier, 2017

O8.2 - TAILORED RECOVERY OF MICROFIBRILLATED CELLULOSE BASED ON PLANT LIGNOCELLULOSE ANATOMY - A CASE STUDY WITH LUPINUS ANGUSTIFOLIUS

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Tailored Recovery of microfibrillated cellulose based on PLANT lignocellulose anatomy - a CASE study with *Lupinus angustifolius*

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This study highlights the holistic utilization of lupin biomass, with seeds serving as a plant-based protein source and residual stem parts explored as a feedstock for lignocellulose-based materials, aligning with a zero-waste strategy. *Lupinus angustifolius* was explored as a model organism for legume crop valorization through an interdisciplinary approach integrating botanical sciences, chemical engineering, and novel imaging techniques [1]. A comprehensive analysis of the plant's chemical composition, histology, and anatomy guided our development of a mild extraction pathway, first evaluating the accessibility of lupin biomass by identifying its hierarchical structures and spatiochemical distribution of biopolymers. Extraction processes were then designed based on mild alkaline treatment, followed by defibrillation, leading to the generation of lupin-derived microfibrillated cellulose (L-MFC).

Optotracing with fluorescent tracer molecules facilitates non-invasive, rapid, and direct visual detection of polysaccharides within the lignocellulosic matrix [2]. Herein, optotracing complemented conventional polysaccharide characterization methods and enabled the real-time visualization of biomass fractionation into distinct structural components, such as libriform-like fibers, lignin-rich vessel elements, and individual fibers. The final L-MFC product consisted of fine, cloud-like cellulose structures interspersed with lignin particles. Through multi-channel confocal fluorescence microscopy, spatial differentiation between cellulose and lignin was achieved, offering high-resolution insights into lignocellulose distribution. This approach enhances process optimization by informing sustainable extraction strategies and advancing lignocellulose recovery methods.

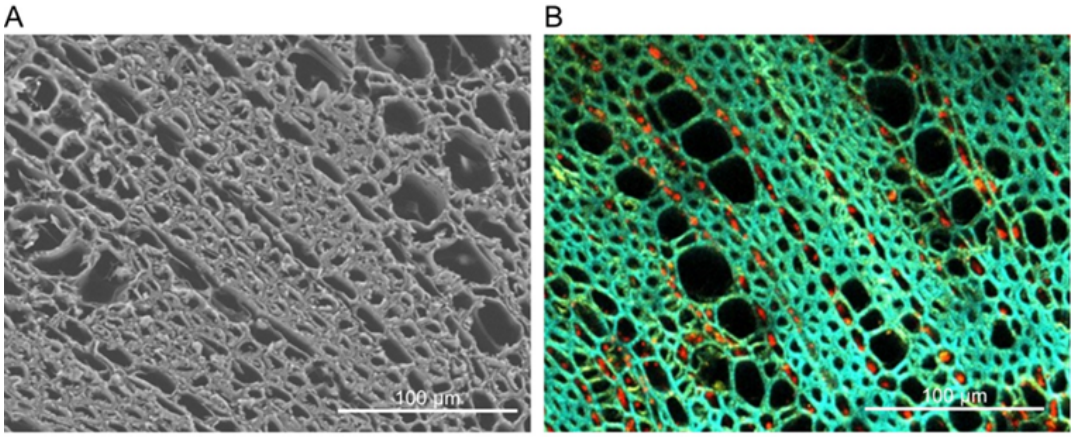

Figure 1. Crossection of a stem from *Lupinus angustifolius*, visualized by A) Scanning electron microscopy, and B) Multi-laser/ multi-detector confocal fluorescence microscopy of tissue stained with Carbotrace 680 [1].

[1] Schmidt, A.E.M.; Choong, F.X.; Richter-Dahlfors, A.; Edlund, U., Adv. Sust. Syst. **2024,** 8(7), 2300632

[2] Choong, F.X.; Bäck, M.; Steiner, S.E.; Melican, K.; Nilsson, K.R.P.; Edlund, U.; Richter-Dahlfors, A., Sci. Rep. **2016**, 6, 35578

O8.3 - Development of a HPAEC-PAD-based screening approach to analyze mannans

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Development of a HPAEC-PAD-based screening approach to analyze mannans

Wagner, L.J.*[a], Bunzel, M.[a]

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Due to its health benefits dietary fiber increasingly come into the focus of human nutrition. Dietary fiber is mainly composed of the polysaccharides of the plant cell wall, which may positively affect human health depending on their structure and their physicochemical and functional properties.

One group of cell wall polysaccharides are mannans, which consist of β-1,4-linked D-mannose units. The linear backbone can also be substituted with D-galactose units via α-1,6 bonds and/or contains β-1,4-linked D-glucose units in the backbone, resulting in galacto-, gluco- and galactoglucomannans, respectively. The various mannan structures can be hydrolyzed into corresponding oligosaccharides by the enzyme mannanase. In addition to mannans, mannooligosaccharides (MOS), which also belong to dietary fiber, are added to food and animal feed due to their positive nutritional properties.

A number of analytical methods are already available for the analysis of polysaccharides like the determination of the monosaccharide composition and the methylation analysis. However, the results are not specific for all polysaccharides, including mannans. Therefore, there is a need for a specific analytical method to structurally analyze mannans. A screening method using high-performance anion exchange chromatography with pulsed amperometric detection (HPAEC-PAD) was developed to obtain information on the structure of mannans. Only MOS with a degree of polymerization of 1 to 6 were commercially available as standard compounds. Therefore, selected glucomannooligosaccharides (GlcMOS) and galactomannooligosaccharides (GalMOS) were isolated after enzymatical release from galactomannan-rich locust bean gum and glucomannan-rich konjac flour. As a result, five GlcMOS with a degree of polymerization of 2 to 4 and four GalMOS with a degree of polymerization of 3, 4, 7 and 8 were obtained with sufficient purity. Following structural characterization, the isolated standard compounds were used for the development of the method.

The developed screening approach was applied to various samples. Different mannans were successfully detected in different samples. For example, GlcMOS were found dominantly in dietary fiber of onion and blackcurrant seeds whereas GalMOS were detected in dietary fiber of coffee beans and coconut. Galactoglucomannooligosaccharides have not been identified in any of the analyzed samples. Therefore, it is only possible to assume the existence of galactoglucomannans based on the presence of both GlcMOS and GalMOS like in the dietary fiber of soy extraction meal. Moreover, different locust bean gums and konjac flours were studied, but there were only small differences in the structures observed. All samples were found to release large amounts of

mannobiose and mannotriose, which can be attributed to the cleavage mechanism of the used mannanase. To sum up, the developed approach is suitable to analyze mannan-containing samples after enzymatic treatment enabling the structural characterization of the contained mannans.

O8.4 - Unraveling Oxidation in Cellulose: Oxidized Functionalities Along and Across the Fiber

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Unraveling Oxidation in Cellulose: OxidiZED functionalities along and across the fiber

Gross Belduma, S.*[a], Sulaeva, I. [b], Kosonen, H. [c], Rosenau T. [a], Potthast, A. [a]

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High-purity cellulose with a well-defined molecular weight distribution is essential for producing cellulose-based materials. A viable approach to obtain a controlled molar mass distribution is electron beam irradiation. Further potential of its application is seen in creating better accessibility of pulp to chemicals and solvents because it affects cellulose independent of crystalline and amorphous regions [1].

During irradiation, free radicals are generated, triggering subsequent chain scission and introduction of oxidized functionalities [2]. On the one hand oxidized functional groups represent predetermined breaking points under alkaline conditions and contribute to color development of the pulp, on the other hand partial oxidation of cellulose provides access to a variety of new products with interesting properties [3]. Even though the extent of these oxidized functional groups and its relationship to the irradiation dose are described for different pulps, the location within irradiated pulp is still unknown.

In our work, we investigate and determine oxidation along and across the irradiated cellulose fiber up to 200 kGy. Newly introduced oxidized groups were determined by fluorescence labeling combined with gel permeation chromatography. β-alkoxy-elimination under alkaline conditions was used to characterize oxidation along the cellulose chain, while a stepwise dissolution approach explores the extent of oxidation across the fiber.

[1] H. Sixta, Ed., Handbook of Pulp, Wiley: Weinheim, 2006; Vol. 1 &Vol. 2

]2] Fischer, K.; Goldberg, W.; Wilke, M., *Lenzinger Berichte* **1985**, *No. 59*

[3] D. Klemm, B. Philipp, T. Heinze, U. Heinze, W. Wagenknecht, Comprehensive Cellulose Chemistry: Functionalization of Cellulose, 1st ed., Wiley, 1998; Vol. 2.

O8.5 - STRUCTURE AND DYNAMIC CHANGES OBSERVED IN THERMOPLASTIC MODIFIED ARABINOXYLAN

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Structure and dynamic changes observed in thermoplastic modified arabinoxylan

Janewithayapun R.*[a,b], Cousin F.[c], Hedenqvist M.[b,d], Larsson A.[a,b], Ström A.[a,b]

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Arabinoxylan (AX) is a major hemicellulose component of cereal and grass cell walls. Through a combination of oxidation, reduction and etherification reactions, it is possible to obtain a thermoplastic AX-based material using 1.0 molar substitution of ether [1]. The materials can be processed by both compression molding and melt extrusion, exhibit tensile strain over 100% and are transparent. Questions were raised as to why the oxidation and reduction step were required, as the oxidation degree used was around 20%, yet good material properties were not reached without the initial two steps. Therefore, a detailed analysis of the changes in AX molecular structure, as well as dynamics were performed. X-ray scattering and high-resolution solution NMR were used to characterize changes in AX chain conformation, and chemical structure. For characterization of the dynamics of the system, dynamic mechanical analysis (DMA), DSC and solid-state NMR methods were studied, giving a description of the system as a function of temperature, while also providing insights on the chemical structure correlated to the motions. By better understanding the fundamental changes in structure and dynamics during that result in thermoplasticity, the effectiveness of modification methods can be evaluated and help to guide the development of synthesis routes for melt-processable polysaccharides in the future.

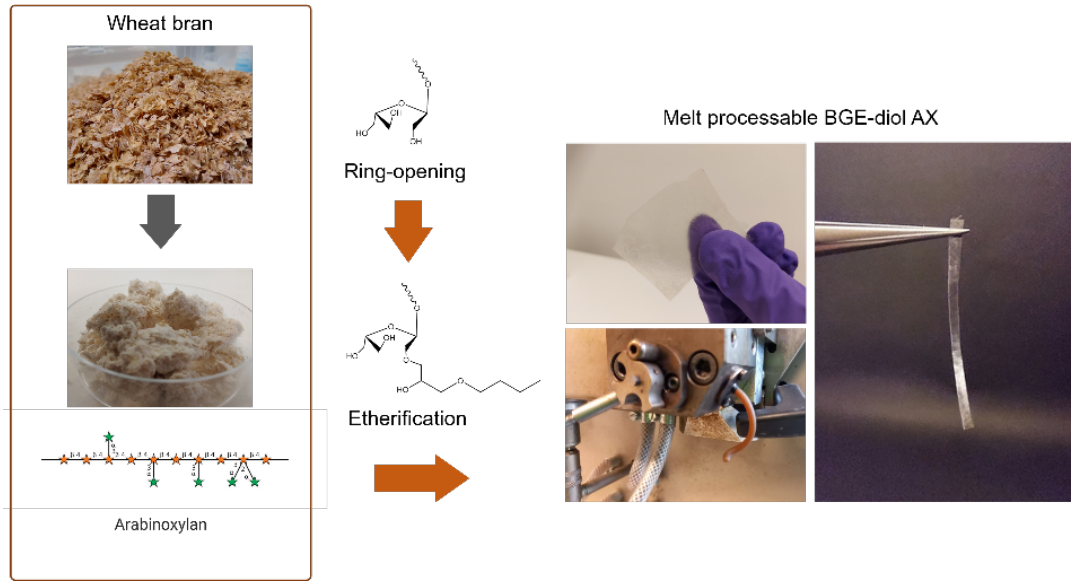

Figure 1. Schematic of the synthesis process for butyl glycidyl ether – dialcohol arabinoxylan (BGE-diol AX)

[1] Janewithayapun, R., et al., *Nanostructures of etherified arabinoxylans and the effect of arabinose content on material properties. Carbohydrate Polymers, 2024.*

Paralell session 9 - Biomedical & Well-Being Applications

2025-08-25
16:00 - 17:00
Paralell session 9 - Biomedical & Well-Being Applications

O9.1 - Multifunctional nanoparticles based on polysaccharides with two-step release behavior

Drug Delivery Systems
Biomedical & Well-being Applications

Multifunctional nanoparticles based on polysaccharides with two-step release behavior

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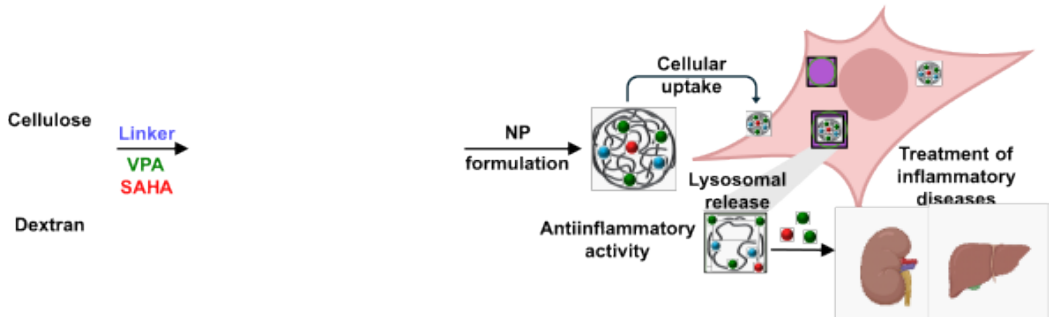
In response to the need for sustainable, biodegradable, and non-toxic alternatives to synthetic polymers, polysaccharides (PS) have gained interest as carriers for pharmaceutically active compounds. Hydrophobic PS derivatives exhibit the ability to self-assemble, making them promissing candidates for the formulation of nanoparticles (NPs) suitable for immobilization and delivery of drugs. Recently, valproic acid (VPA) has gained interest for the treatment of inflammatory diseases due to its ability to act as a Histone deacetylases inhibitor (HDACi). However, VPA's short serum half-life, poor solubility in aqueous media, and potential side effects pose significant challenges for application. VPA could be attached to various PS by conventional modification reactions. Hydrophobic valproate derivatives are capable of forming uniformly shaped NPs with diameters around 150-200 nm.[1] Attachment of sulfuric acid half-ester moieties led to cellulose valproate sulfate (CV-S); their NPs exhibit cellular uptake, no toxicity and facilitate intracellular release of VPA within lysosomal areas.[2]



However, achieving a delicate balance between the stability of a chemically immobilized drug and favorable release behavior at the site of interest is challenging. To address this, the present work focuses on attaching different classes of HDACi by unconventional PS modification techniques, thereby enhancing their efficacy and therapeutic potential. Synthesis efforts are directed towards the chemical attachment of VPA as a thioester, since thioesters are known to be more sensitive to hydrolysis than their conventional ester counterparts. In addition to VPA as the primary compound, suberoylanilide hydroxamic acid (SAHA), a potent HDACi, is attached to investigate PS-based multi-drug loaded particles with a two-step release behavior. SAHA cannot be directly attached to the PS backbone due to the lack of a suitable functional group. To overcome this limitation, novel SAHA prodrugs were developed that possess predetermined physiological breaking points. These

prodrugs exhibit reactivity in reliable and efficient click chemistry reactions with PS derivatives. Additionally, efforts will be directed towards incorporating dyes and targeting units to track NP localization within biological systems while potentially enhancing tissue specificity.

Figure 1: Polysaccharide derivatization with linkers and HDACi (VPA, SAHA), NP formulation and investigation of biological activity.

[1] H. Lindemann, et al., *Macromol. Biosci.* **2020**, *20*, 2000039.

[2] M. Kühne, et al., *J. Control. Release* **2021**, *329*, 717-730.

O9.2 - CARBOXYMETHYLCELLULOSE-FUCOIDAN DISSOLVABLE MICRONEEDLES FOR MINIMALLY INVASIVE AND TARGETED MELANOMA TREATMENT

Drug Delivery Systems
Biomedical & Well-being Applications

Carboxymethylcellulose-fucoidan dissolvable microneedles for Minimally Invasive and targeted Melanoma Treatment

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Melanoma is a highly aggressive skin cancer with high global morbidity and mortality [1]. Following tumor excision, most patients are required to undergo traditional treatment strategies (e.g., chemotherapy, radiotherapy) that are often associated with considerable systemic side effects, prompting the exploration of alternatives, such as the use of natural compounds with intrinsic biological activities. Fucoidan, a sulfated polysaccharide extracted from brown algae, has shown promising anticancer effects, through inhibition of melanoma cell growth and induction of apoptosis [2]. However, the limited bioavailability of this macromolecule restricts its clinical application. Therefore, the development of novel delivery platforms is essential to enhance its effectiveness. One promising solution lies in the development of microneedles (MNs), which are minimally invasive drug delivery systems that bypass the *stratum corneum* and create micron-sized channels in the skin, facilitating the delivery of drugs or bioactive compounds [3].

In this communication, we report the fabrication and characterization of polysaccharide dissolvable microneedle patches, composed of carboxymethylcellulose (CMC) and fucoidan (Fuc), using an eco-friendly and cost-effective micromolding technique. With an average height of 456 μm and sharp tips, the microneedles exert the necessary force (up to 1.1 N *per* needle) to successfully penetrate human skin (up to 453 μm, *ex vivo*) and dissolve rapidly upon insertion (<15 min, *in vitro*), ensuring that fucoidan is efficiently released into the skin. Notably, the CMC_Fuc MNs exhibited significant anticancer activity, reducing the viability of melanoma cells (A375) by 41% and 83% after 24 h and 48 h of exposure, respectively. Furthermore, *in vitro* studies in a 3D melanoma model confirmed the enhanced antineoplastic effect of this system, with a 56% reduction of A375 cell viability, after 48 h. Overall, our results underscore the potential of the CMC_Fuc MNs as a novel adjuvant therapy for melanoma, providing a more efficient, localized, and minimally invasive therapeutic option for post-operative cancer patients.

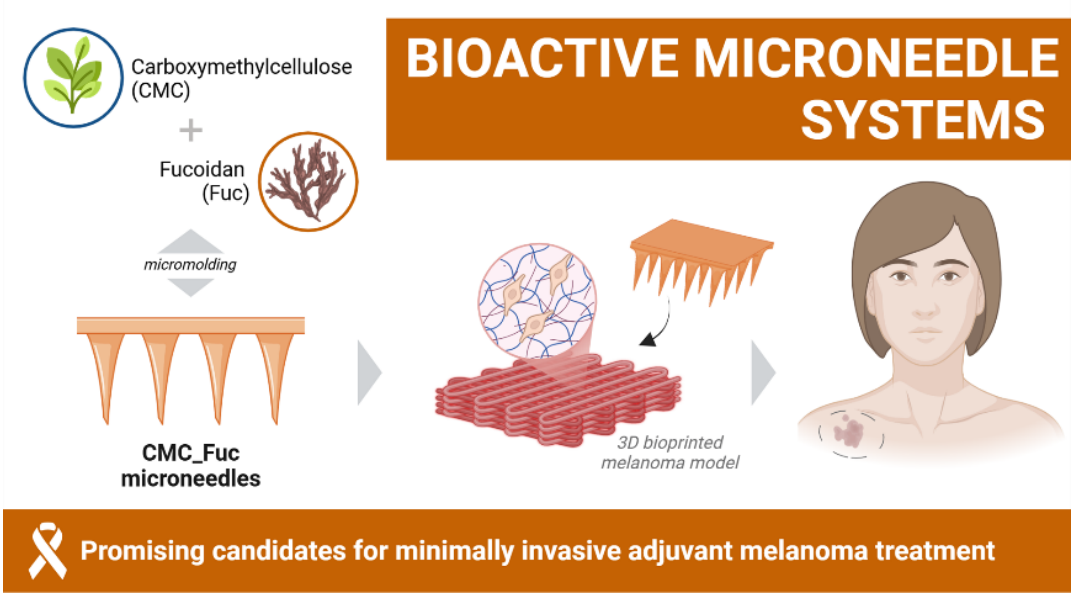

Figure 1. Scheme of the fabrication of bioactive microneedle systems for melanoma therapy.

[1] G. V. Long et al., *Lancet*. **2023**, *402*, 485–502; [2] O.S. Malyarenko et al., *Int. J. Biol. Macromol.* **2021**, *185,* 31–39; [3] A.C.Q. Silva et al., *Macromol. Biosci.* **2023,** *23,* 2200323.

Acknowledgments: This work was developed within the scope of the project CICECO-Aveiro Institute of Materials, UIDB/50011/2020 (DOI 10.54499/UIDB/50011/2020), UIDP/50011/2020 (DOI 10.54499/UIDP/50011/2020) & LA/P/0006/2020 (DOI 10.54499/LA/P/0006/2020), financed by national funds through the FCT/MEC (PIDDAC). FCT is acknowledged for the research contracts under Scientific Employment Stimulus to C.S.R.F. (DOI 10.54499/CEECIND/00464/2017/CP1459/CT0033), C.V. (DOI 10.54499/2021.01571.CEECIND/CP1659/CT0024).

O9.3 - HYBRID HYDROGEL/ NANOPARTICLES DUAL-CANCER DRUG DELIVERY SYSTEM BASED ON AMPHIPHILIC POLYSACCHARIDE-POLYESTER COPOLYMERS

Drug Delivery Systems
Biomedical & Well-being Applications

Hybrid hydrogel/ nanOparticles dual-CANCER drug delivery system based on amphiphilic POLYSACCHARIDE-POLYESTER copolymerS

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Triple-negative breast cancer is an aggressive subtype of cancer with limited targeted therapy options, high recurrence rates and significant treatment challenges. Combination theparies, integrating chemotherapy and immunotherapy, are emerging as promising strategies to enhance treatment efficacy while minimizing adverse effects. [1] This project aims at designing a novel hybrid dual-drug delivery system composed of a biodegradable polymeric hydrogel incorporating anticancer drug-loaded nanoparticles (NPs) and monoclonal antibody to achieve simultaneously and independant drugs release. (Figure 1)

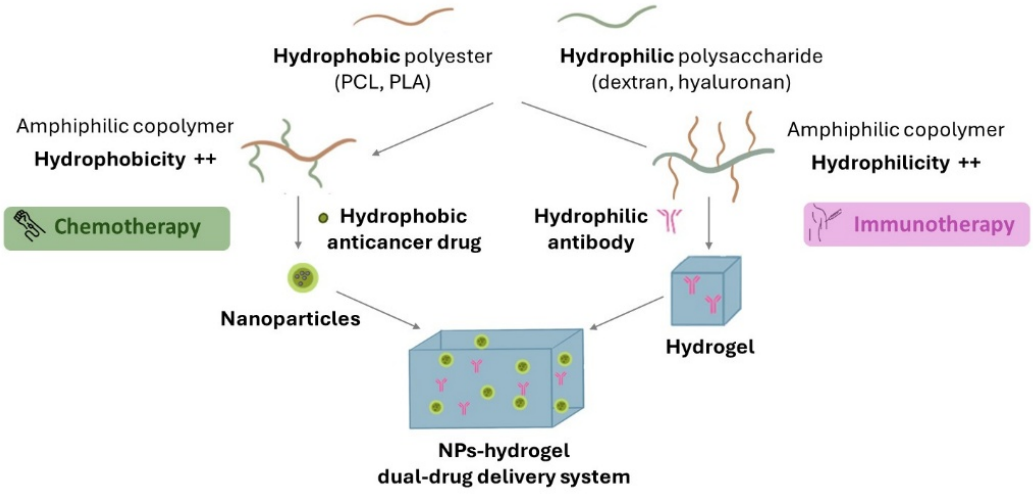

Figure 1: Design of hybrid hydrogel/nanoparticles dual-cancer drug delivery system

The key innovation lies in utilizing a single family of amphiphilic biodegradable polyester-polysaccharide copolymers to design both hydrogel and NPs. Various batches of copolymers, *i.e.* poly-ε-caprolactone-dextran (PCL-Dex) or PCL-hyaluronic acid (PCL-HA), with different hydrophilic-lipophilic balances were synthesized. [2, 3]

Paclitaxel (PTX)-loaded NPs were prepared and characterized in terms of size (100-200 nm), drug loading (10-13%) and encapsulation efficiency (40-50%). *In vitro* studies showed a sustained PTX release of around 30 % within 30 days for PCL-Dex NPs. *In vitro* cytotoxicity and cell internalization studies showed a better and more selective anticancer effect of PCL-HA NPs compared to PCL-Dex NPs. *In vivo* studies on zebra fish embryo models revealed homogeneous biodistribution of both NPs after intravenous injection.

Furthermore, hydrogels based on dextran-PCL copolymer were prepared. Their rheofluidic behavior, their injectability and their cytocompatibility were demonstrated.

In vitro and *in vivo* cytotoxicity, anticancer activity and NPs release of the combined hydrogel-NPs system are currently under investigation.

[1] Zhang, R.X. et al, *Journal of Controlled Release* **2016**, *240*, 489-503

[2] Al Samad, A. et al, *Polymer Chemistry*, **2015**, *6* (28), 5093–5102

[3] Delorme, V. et al, *Carbohydrate Polymers,* **2020***, 232*, 115764

Paralell session 10 - Materials & Engineering

2025-08-25
16:00 - 17:40
Paralell session 10 - Materials & Engineering

O10.1 - From all-cellulose composites to activated carbon: Influence of precursor structure and KOH concentration

Nanostructured Materials
Materials & Engineering

From all-cellulose composites to activated carbon: Influence of precursor structure and KOH concentration

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Cellulosic biomass is widely used as precursor for activated carbon (AC), a versatile material employed in water purification, gas adsorption, and energy storage applications. One-step chemical activation with potassium hydroxide solution (KOH) is a promising approach to produce AC, where structurally integrated potassium significantly enhances porosity through vaporization at temperatures over 700°C [1]. While current research often focuses on high-temperature activation conditions, the mercerization of cellulose at lower temperatures, which facilitates effective potassium integration, is frequently overlooked. Mercerization efficiency depends not only on the KOH solution concentration but also on the precursor's structural properties, particularly on the proportion of crystalline and amorphous regions.

Here we demonstrate the use of all-cellulose composites (ACCs) with varied compositions as AC precursors, to investigate how structural differences in precursors influence mercerization and, consequently, AC characteristics. Precursor properties were characterized using traditional paper analysis methods, scanning electron microscopy (SEM), inverse gas chromatography (IGC), and small-angle X-ray scattering (SAXS). The resulting activated carbons were analyzed through nitrogen adsorption, transmission electron microscopy (TEM), SEM, and SAXS.

Our findings demonstrate that compositional variations in ACCs modify the surface energy as well as its macro- and microscale structure, thereby leading to distinct activated carbon characteristics. Tuning the mercerization process by the KOH concentration enabled the improvement of activation outcomes, including specific surface area, pore size distribution, and pore morphology. These insights contribute to the understanding of precursor-KOH interaction, enabling optimization and

targeted design of activated carbons.

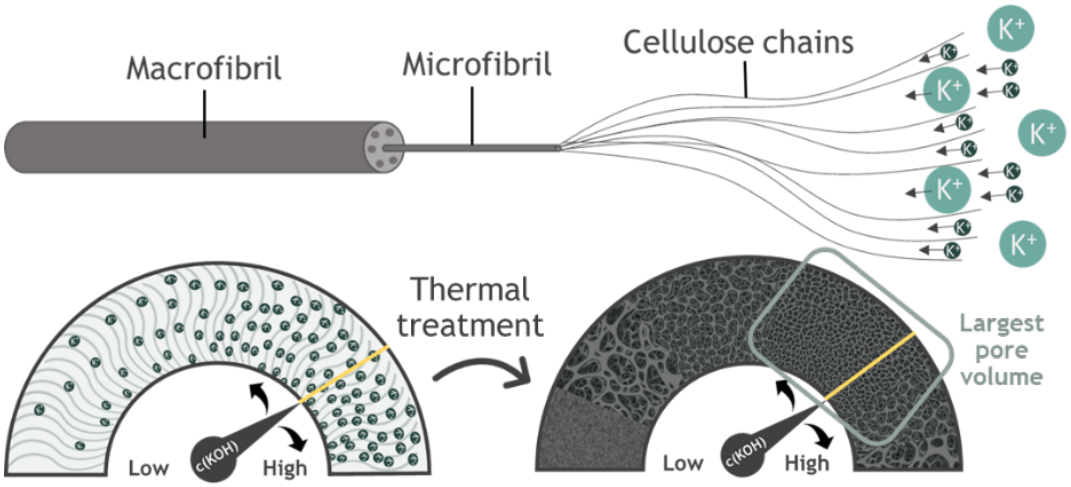

Figure 1. Effect of potassium incorporation level into precursor structure on AC porosity.

[1] W. Chen, M. Gong, K. Li, M. Xia *et al.*, *Applied Energy,* vol. 278, p. 115730, 2020.

O10.2 - ELECTROSPINNING OF NANOCELLULOSE-STABILIZED EMULSIONS TOWARD MULTIPHASIC FIBERS

Nanostructured Materials
Materials & Engineering

Electrospinning of Nanocellulose-stabilized emulsions toward multiphasic fibers

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In Pickering Emulsions (PEs), multiphasic systems are stabilized by particles. By electrospinning, these systems can be converted into fibers that preserve the multiphasic character and are able, for instance, to store active compounds through core-shell architectures. Due to this exceptional ability, such fibers have high promises for advanced material applications in drug delivery, tissue engineering, filtration, or catalysis. The generated core-shell architecture thereby ensures high encapsulation efficiency and high control over the release kinetics of active agents. This study explores fundamental principles of PE electrospinning based on polysaccharides, such as dextran or hydroxypropyl methylcellulose that later form the multiphasic fiber matrix, and cellulose nanocrystals as emulsion stabilizers. To achieve fiber spinnability, we present strategies for tailoring oil-in-water and water-in-water PEs, for instance, by selecting suitable oil or water-soluble polymers, or by varying their concentration and the phase ratio, as well as by adapting the concentration of the particle stabilizer. The phase behavior and stability of PEs are analyzed by fluorescence microscopy, using selective dyes for each of the polymer phases. For fiber characterization, scanning electron microscopy (SEM) and transmission electron microscopy (TEM) were used to analyze the fiber morphologies and to confirm the resulting core-shell architecture, respectively. Ultimately, we will show how PE electrospinning can be a promising and, more importantly, scalable alternative to multiaxial electrospinning for the production of multiphasic and functional fibers.

O10.3 - CELLULOSE-ENABLED MULTIPHASIC SYSTEMS: TAILORING EMULSION STABILIZATION AND RHEOLOGY BY AN ALL-IN-ONE APPROACH

Nanostructured Materials
Materials & Engineering

Cellulose-enabled multiphasic systems: tailoring emulsion stabilization and rheology by an all-in-one approach

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Traditionally, emulsions achieve stability via synthetic surfactants such as sodium lauryl sulfate (SLS), cetyltrimethylammonium bromide (CTAB), and sodium dodecyl sulfate (SDS), which reduce interfacial tension at liquid-liquid interfaces. These surfactants, although cost-effective, pose environmental concerns due to their persistence, bioaccumulation, and adverse effects on microorganisms, flora, and fauna. Bio-based alternatives, such as lecithin, protein-based surfactants and rhamnolipids (RLs), are available but less prevalent due to higher costs and limited market competitiveness. Pickering emulsions, stabilized by solid micro/nanoparticles instead of surfactants, offer a promising solution with applications in water-based coatings and active formulations. Out of these stabilizers, cellulose stands out as a sustainable option. Concretelly, cellulose nanofibers (CNFs) offer tailored surface functionality, electrostatic properties, and morphology. This versatility enables CNFs to function as both an emulsion stabilizer and a rheology modifier, making it ideal for applications such as coatings that demand a balance of performance, viscosity, and solid content.

The present work consists of two different parts, aiming at both providing a comprehensive understanding on on how oil-in-water (O/W) emulsions can be tailored and providing case studies on the use of these multiphasic systems for value added applications. On the one hand, the work covers how appropriately tuning CNF surface charge, morphology, and content, along with processing conditions during emulsion preparation can impact O/W emulsions properties. Concretely, CNFs were labelled with calcofluor white (CFW), while the oil phase was stained with nile red, allowing their identification under appropriate light conditions in confocal microscopy. This allowed identifying those fibers retained at the oil-water interface, along with those that remained at the continuous phase (water) contributing to the rheology of the emulsion. On the other hand, the presentation will also provide insights into the use of these emulsions as paper coating, with special emphasis in antimicrobial and high-barrier coatings for food packaging applications, but also for the development of paper-based sensors that can detect some heavy metals, such as iron(III) or mercury(II), or amines and ammonia from rotten fish in packaging applications.

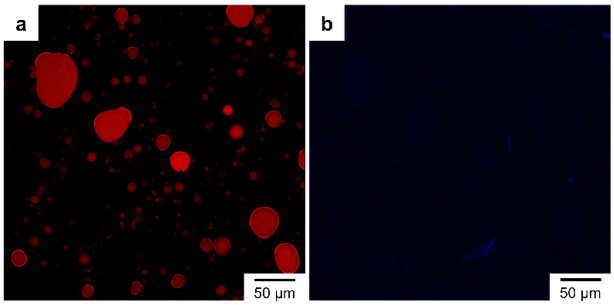

Figure 1. Confocal microscopy of nile red-stained cardamom O/W emulsions stabilized with CFW-labelled CNFs at 520 nm (a) and 400 nm (b) of wavelength (λ_{ex})

O10.4 - FUNCTIONAL NANOFIBERS BY UTILIZING THE NATURAL COMPOSITION OF BIO- RESOURCES

Nanostructured Materials
Materials & Engineering

FUNCTIONAL NANOFIBERS by Utilizing the natural composition of bio- resources

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Separation of functional nanofibers from bio-based residues by utilizing their natural composition promotes an increased resource efficiency combined with the development of nanofibers with specific functionality. The diversity found in natural materials gives rise to considerable variation in composition, biofunctions and robustness of the cell wall structure [1]. This, in turn, will further dictate how much effort is required to isolate building blocks from the plant and pose challenges as to how to make the most of them when refining and utilizing these resources. Within a biorefinery perspective, exploiting cellulosic biomass, from different industrial and agricultural residues is advantageous both from an environmental and economic point of view. This applies to the entire chain of resources, from sustainable use of raw materials to the reduction of residues by means of waste treatment or disposal, and furthermore to the development of high-value-added products. We have made previous studies where cellulose nanofibers from different industrial bio-based residues have been separated after chemical pretreatment with a high yield and efficiency in the presence of its non-cellulosic components such as lignin, hemicellulose, pectin, starch, and alginate [3-6]. By making use of the natural composition that the biomass offers, in turn reducing fractionation, or pretreatment steps, not only promote energy efficient conversion, but also contribute to an overall more eco-efficient process [4]. Furthermore, specific properties such as super-absorption, fire retardant or increased hydrophobicity can be achieved and tuned for various applications [3-6]. For example, the role of hemicellulose or mycelia in the network formation of wood nanofibers display intrinsic characteristics that could serve as a template for the future development of resource-efficient functional materials.

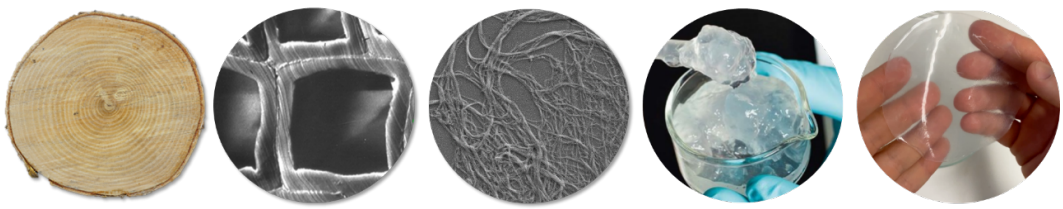

Figure 1: From wood to nanofiber gel and templated wood nanofiber network.

[1] Gibson L.J., J. *Royal Soc. Interface*, 9, 2749–2766, 2012.

[2] Hassan M., Berglund L., Hassan E., Abou-Zeid R., et al. *Cellulose*, 25(5), 2939-2953, 2018.

[3] Berglund L., Breedveld L., Oksman K., *J. Cleaner prod*. 255, 120274, 2020.

[4] Berglund L., Rakar J., Junker P.E., Forsberg F., Oksman K., *ACS Appl. Bio Mater*. 3, 6510, 2020.

[5] Squinca P., Berglund L., Hanna K., Rakar J., Junker J., Khalaf H., Farinas CS., Oksman K. *Biomacromolecules,* 22(8), 3202-3215, 2021.

O10.5 - Digital light processing (DLP) 3D-fabricated PEG hydrogel toughened by thermoresponsive and photoreactive xylan derivatives

Nanostructured Materials
Materials & Engineering

Digital light processing (DLP) 3D-fabricated PEG hydrogel toughened by thermoresponsive and photoreactive xylan Derivatives

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Developing naturally derived thermoresponsive biopolymers in macromolecular design and synthesis is attractive but still challenging [1]. Here, debranched xylan (D-xylan), a chemically engineered linear polysaccharide of *β*-1,4-linked xylose, is used to construct thermoresponsive and photoreactive polymer of xylan-*g*-allyl glycidyl ether (xylan-*g*-AGE) via grafting of AGE to D-xylan [2]. Compared to cellulose, D-xylan allows a greater degree of spatial coordination for sidechains, due to the inherited absence of exocyclic CH_2OH on C5. The hydrophobic interactions and reformed H-bonds dominant induced the transformation of xylan-*g*-AGE from solvated coil chain to self-assembled mesoglobules in an aqueous solution upon heating. When xylan-*g*-AGE is incorporated into photoresins for fabricating hydrogels with high geometric fidelity via DLP 3D printing, its solvated state enhances the stiffness of PEG hydrogels by increasing the crosslink density of the available AGE moieties and accelerating the crosslinking rate. In contrast, the self-assembled xylan-*g*-AGE improves the toughness of PEG hydrogels by leveraging the "dual chemically independent domains" strategy, which effectively integrates the tough PEG domain with the soft, self-assembled xylan-*g*-AGE domain. The MXene sheet serves as a multifunctional additive in photoresins, effectively reducing light scattering during DLP printing while imparting electrical conductivity to the resulting hydrogel, enabling its application as a wearable strain sensor.

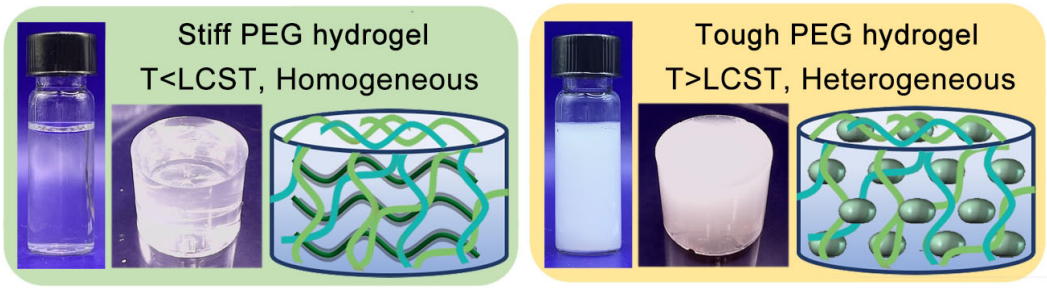

Figure 1. Photographs of xylan-based photoresins and hydrogels photo-crosslinked below or above its lower critical solution temperature

[1] Wang, Wei, et al. *Advanced Materials*, **2022**, *34*(46), 2107877. DOI: 10.1002/adma.202107877.

[2] Zhang, Yidong, et al. *Carbohydrate Polymers*, **2024**, 335, 122089. DOI: 10.1016/j.carbpol.2024.122089.

Parallel session 11 - Materials & Engineering

2025-08-26
11:30 - 12:10
Parallel session 11 - Materials & Engineering

O11.1 - Mushroom Makeover: Revealing the Potential of Mushroom Residues in Skincare

Sustainable Materials/Circular Economy
Materials & Engineering

Mushroom Makeover: Revealing the Potential of Mushroom Residues in Skincare

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Commercial mushroom production generates significant amounts of fruiting body waste, with up to 20-30% of harvested mushrooms being discarded due to mishappen caps or stalks [1]. Drawing inspiration from recent advancements in chitin-glucan nanofilm research [2], we propose repurposing waste mushrooms into value-added materials. By leveraging the chitin-glucan complex found in common mushrooms, we developed flexible chitin-glucan sheets with an innovative application as a fungi-based cosmetic sheet mask (see figure). The chitin-glucan complex was extracted from two different fungal types, namely white button mushroom (Agaricus bisporus) and lion's mane mushroom (Hericium erinaceus), both containing numerous valuable components beneficial for skin health [3]. Mild extraction processes were chosen to preserve cosmetical valuable compounds in the extracted chitin-glucan biomass. The resulting materials were characterized by porosity, mechanical properties, surface properties, water absorption and disintegration. Our findings demonstrate the potential of fungi-derived chitin-glucan sheets as viable alternatives to conventional cosmetic sheet masks. The developed materials exhibited tensile strength (up to 12.3 MPa) and strain to failure (up to 44.9%), comparable to commercial products. Moreover, our study highlights the eco-friendly and cost-effective nature of fungi-derived materials. By repurposing waste mushrooms, we not only address waste management challenges but also contribute to the development of a more sustainable and circular economy. The utilization of mild extraction processes together with the scalability of the sheet preparation enables cost-effective production, offering an economically viable solution for the cosmetic sector.

Figure 1. Final cosmetic sheet mask derived from white button mushrooms

[1] Guo, J., Zhang, M. & Fang, Z. Valorization of mushroom by-products: a review. J. Sci. Food Agric. **2022**, 102, 5593–5605.

[2] Nawawi, W. M., Lee, K.-Y., Kontturi, E., Murphy, R. J. & Bismarck, A. Chitin Nanopaper from Mushroom Extract: Natural Composite of Nanofibers and Glucan from a Single Biobased Source. ACS Sustain. Chem. Eng. **2019**, 7, 6492–6496.

[3] Hyde, K.D., Bahkali, A.H. & Moslem, M.A. Fungi—an unusual source for cosmetics. Fungal Diversity **2010**, 43, 1–9.

O11.2 - HARNESSING MYCELIUM TO UPCYCLE TEXTILE WASTE INTO ECO-FRIENDLY FABRIC BIOCOMPOSITES

Sustainable Materials/Circular Economy
Materials & Engineering

Harnessing Mycelium to Upcycle Textile Waste into Eco-Friendly Fabric Biocomposites

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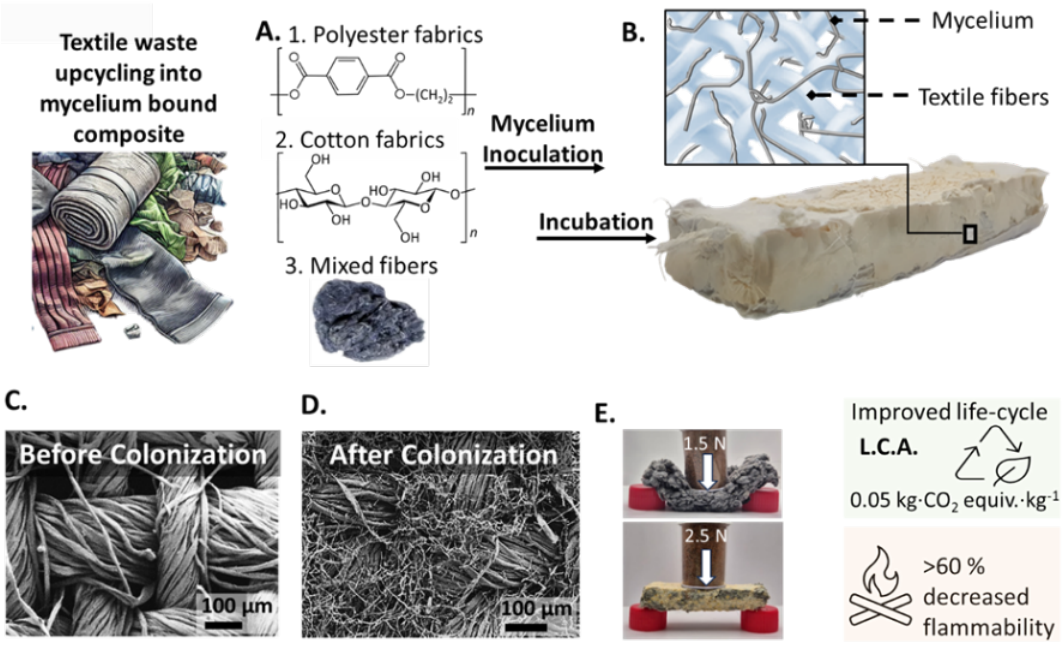
Mycelium, the fibrous and chitin-rich root structure of fungi, has gained attention as a sustainable alternative to conventional materials like plastic packaging and leather [1]. Its natural ability to grow on diverse substrates, combined with its low environmental footprint, makes it an ideal candidate for biofabricated composites [2].



In this study, we investigated the in-situ growth of *Pleurotus ostreatus* on various textile substrates (***Figure 1A***) including cotton, polyester, and mixed shredded fibers (lint). The resulting biocomposites (***Figure 1B***) exhibited distinct colonization patterns(***Figure 1C and D***) depending on the textile type and inoculation conditions. Cotton-based composites with a 50:50 spawn-to-textile ratio demonstrated the best mechanical performance, achieving a flexural strength of 82.5 kPa and toughness of 3298 kJ/m³. Flammability tests showed that cotton composites self-extinguished within 30 seconds, with only 40% of the surface area burned. Polyester-based composites also showed a

reduction in flame propagation, indicating potential for safer material applications.

Figure 1: Schematics of the biocomposite preparation using textile waste/lint. A. Illustration of textile wastes types evaluated herein namely cotton and polyester fabrics as well as mixed shredded fibers. B. Image of fabricated mycelium composite, Inset - Graphical presentation of mycelium growing in the textile fabrics

A life cycle assessment (LCA) of biobrick production showed a climate change impact of 0.05 to 4.28 kg CO_2-equivalent per kilogram (***Figure 1E***), depending on whether a renewable or fossil-based energy mix was used. These results underscore the potential of mycelium as a natural binder for upcycled textiles, offering a scalable, eco-friendly approach to sustainable material innovation.

[1] Joseph Kinyanjui Muiruri, Jayven Chee Chuan Yeo, Qiang Zhu, Enyi Ye, Xian Jun Loh, and Zibiao Li *ACS Sustain. Chem. Eng.* 2023 11 (18), 6801-6821

[2] Wenjing Sun, Mehdi Tajvidi, Caitlin Howell, and Christopher G. Hunt *ACS Appl. Mater. Interfaces.* 2020 12 (51), 57431-57440

Parallel session 12 - Food & Nutrition

2025-08-26
11:30 - 12:30
Parallel session 12 - Food & Nutrition

O12.1 - PRODUCTION AND CHARACTERIZATION OF MECHANIC-ENZYMATIC TREATED FOOD BY-PRODUCT CARROT POMACE

Dietary Fiber
Food & Nutrition

Production and Characterization of mechanic-enzymatic treated food by-product carrot pomace

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[a] Institute of Applied Biosciences, Department of Food Chemistry and Phytochemistry, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

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By-products from the fruit and vegetable processing industry are often rich in dietary fiber. Depending on the structure, various health benefits, such as prebiotic or anticarcinogenic effects, are postulated for dietary fiber. The incorporation of fiber-rich by-products into food products is therefore both sustainable and desirable from a nutritional point of view. However, fiber enrichment of foods is mostly limited by sensory and functionality-based changes such as gel formation. By combining mechanical treatment with enzymatic hydrolysis, it was possible to produce fiber preparations with low viscosity from the fiber-rich by-product carrot pomace. These preparations could be incorporated into beverages and yoghurts without compromising sensory properties.

For this purpose, the combined mechanic-enzymatic treatment of carrot pomace was adapted to its cell wall structure. Enzymes (arabinanase, cellulase, galactanase, polygalacturonanase and/or pectin lyase) were selected based on the dominant cell wall polysaccharides of carrot pomace. Both composition of the enzyme mixture and enzyme-substrate ratio were optimized with respect to the functional properties of the hydrolysate and a low release of mono- and disaccharides. Conditions of mechanical treatment were adjusted, focusing on formation of stable suspensions. The impact of the order of mechanical treatment and enzymatic hydrolysis was analyzed, too. Additionally, the need for mechanic pre-treatment of the carrot pomace was studied.

The combined mechanic-enzymatic treatment led to a reduction in dietary fiber, which was mainly due to a decrease (up to 50%) in the amount of insoluble dietary fiber. As intended, the proportion of soluble and low-molecular weight soluble dietary fibers mostly increased during the treatment. However, mono- and disaccharides were released by enzymatic hydrolysis of poly- and oligosaccharides from carrot pomace, too. Partially, high amounts of monosaccharides (up to 33%) were detected. Selected low-viscous (7-15 mPa·s) dietary fiber preparations were characterized in detail regarding structural modifications of carrot pomace dietary fiber compounds. These data indicate that changes in structure and amount of dietary fiber are caused by degradation of cellulose and pectin structures (arabinans, galactans, and homogalacturonans). To determine released, structurally different oligosaccharides, HPAEC-PAD/MS-based analysis was optimized and a

HILIC-PDA(-MS)-based approach was newly developed. Results indicate a preferential formation of short-chain arabino-, cello-, galacto- and/or galacturonic acid oligosaccharides (degree of polymerization: 3-4) by enzymes used for treatment. However, the total oligosaccharide content was comparably low (≤2%) in all low-viscous dietary fiber preparations

In summary the treated carrot pomace is suitable for enriching foods with dietary fiber and reducing the addition of sugar to food products. While enzymatic hydrolysis was important to degrade polysaccharides, mechanic treatment was necessary to improve the functional properties of the carrot pomace.

This IGF Project (21616N) of the FEI was supported via AiF within the program for promoting the Industrial Collective Research (IGF) of the Federal Ministry of Economic Affairs and Climate Action (BMWK), based on a resolution of the German Parliament.

O12.2 - MULTI-SCALE STRUCTURAL STUDIES OF WHEAT BRAN USING X-RAY BASED TECHNIQUES

Other
Food & Nutrition

multi-scale structural studies of wheat bran

using x-ray based techniques

Ladd-Parada, M.*[a], Sivan, P.[a], Wahlström, N.[a], Carlsson, J.[a], Rymyk, N.[a], Rebaque, D.[a,b], Zhou, T.[c], Vilaplana, F.[a]

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Wheat bran is one of the major by-products of the wheat processing industry. It is mostly composed of structural polysaccharides (60%), from which arabinoxylan (AX) is the most abundant one representing 20-40% of the total content [1,2]. In previous works we have developed wet processing methods using subcritical water, alkaline treatments and enzyme technology to extract AX from wheat bran. A common challenge for these processes is the low extraction yield [3, 4], which is related to the recalcitrance of the cereal cell walls caused by the complex physicochemical interactions between the molecular components. To help understand the origin of the recalcitrance, we have performed a study of the structural changes in wheat bran using a combination of fluorescence microscopy, X-ray tomography, and X-ray scattering.

Fluorescence microscopy is invaluable to understand the localisation of different compounds in the wheat bran, while having the disadvantage of only allowing for one plane evaluation. X-ray tomography allowed us to observe the morphological differences from a 3D perspective, and has the strong advantage of allowing us to segment virtually the bran into its different sections. However, the data-analysis is time consuming. X-ray scattering can be performed in bulk, or using a scanning approach to evaluate if there is any variability in the structure of the bran across one of its faces. The integration of these approaches contributes to a detailed understanding of the heterogeneous localisation of the wheat bran components after different wet processes, and how wheat bran's structure changes as an effect of the different extraction processes.

1. S Apprich, Ö Tirpanalan, J Hell, M Reisinger, S Börhmdorfer, S Siebenhandl-Ehn, S Novalin & W Kneifel. *LWT - Food Science and Technology* **56**, 222, 2014

2. MS Izydorczyk & CG Biliaderis. *Carbohydrate Polymers* **28**, 33, 1995

3. A.C. Ruthes, R.C. Rudjito, J. Rencoret, A. Gutiérrez, J.C. del Río, A. Jiménez-Quero, and F. Vilaplana, *ACS Sustainable Chemistry & Engineering* **8** (18), 7192-7204, 2020

4. R. C. Rudjito, A. C. Matute, A. Jiménez-Quero, L. Olsson, M. A. Stringer, KBRM Krogh, J Eklöf, F Vilaplana. *Bioresource Technology 395, 130387, 2024*

O12.3 - MACROALGAE: AN INTERESTING SOURCE OF HIGHLY DIVERSIFIED SPECIFIC POLYSACCHARIDES – PSAMAL PROJECT

Extraction & Purification
Chemistry, Biology & Physics

Macroalgae: an interesting source of highly diversified specific polysaccharides – PSAMAL Project

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Seaweed are used by coastal populations for centuries for their high nutritional value, but today represents a major economic development challenge. Macroalgae are a high-potential renewable bioresources with a fast-growing value-added market. Among many bioactive components derived from algae, glycans are polysaccharides of variable size, distinguished by their multiple properties, especially antioxidant, antimicrobial, anticarcinogenic, immunostimulant and anti-inflammatory ones [1]. These algal polysaccharide bioactivities are mainly attributed to the complex, highly branched polymeric structures and specific chemical compositions, including sulfated groups. For example, galactans and fucoidans are sulfated polysaccharides of interest (Figure 1A). Thus, algal polysaccharides show great potential for applications in the food and feed, pharmaceutical, phytosanitary, nutraceutical and cosmetic sectors, justified by the attraction of active ingredients of natural origin.Nevertheless, despite their potential to generate numerous high value-added products and biomolecules, algae remain under-utilized in Europe. The present work focuses on the evaluation of polysaccharidic content (carrageenan, xylan, galactan, fucoidan) of three macroalgae cultivated in our regions (Opalgue project), two species of red algae, i.e. Palmaria palmata (PP) and Porphyra purpurea (PU), and a brown one, Saccharina latissima (SL). Various extractions and treatments were carried out. Conventional maceration-type extractions in H_2O/Ethanol mixtures at 40°C, 150rpm for 4h and polysaccharide-selective extractions in H_2O at 80°C, 150rpm for 2h were compared. Total phenolic and flavonoic content (TPC and TFC), total sugars (Figure 1B) and sulfates were determined using UV spectrophotometric methods, as well as polysaccharidic chemical characterization.

A

B

Figure 1: Polysaccharides found in algae (A). Total sugar content in mgEG/gDE for non-selective extraction in Porphyra purpurea.

For example, the selective polysaccharide treatment condition provided significant total sugar quantities up to 764 mgEG/gDE (mg glucose equivalent/g dry extract) instead of 400 mgEG/gDE in

non-selective aqueous extraction in *Porphyra* extract. At the same time, the antioxidant activities of every extract were carried out. These extracts are currently tested for their antimicrobial, antifungal and biostimulant activity (Malgabio project). In the near future, tests to obtain oligosaccharides from algal polysaccharides will be carried out in the laboratory, by chemical, mechanochemical and enzymatic processes.

[1] Food Rev International. 2024, 40(5), 1312–1347.doi.org/10.1080/87559129.2023.2212055.

[2] Ann Bot. 2014 Oct;114(6):1203-16. doi: 10.1093/aob/mcu096. Epub 2014 May 29.

Parallel session 13 - Chemistry, Biology & Physics

2025-08-26
11:30 - 12:30
Parallel session 13 - Chemistry, Biology & Physics

O13.1 - Probing Molecular Architecture in Chemically Modified Celluloses Using Dynamic Nuclear Polarization Solid-State NMR Spectroscopy

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Probing Molecular Architecture in Chemically Modified Celluloses Using Dynamic nuclear polarization Solid-State NMR Spectroscopy

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Efficient biomass conversion is central to advancing applications of renewable materials, but its success depends on unraveling the intricate chemical structures and reaction mechanisms of complex bio-derived materials. Nuclear magnetic resonance (NMR) spectroscopy, particularly with dynamic nuclear polarization (DNP) enhancement, provides an unparalleled platform for characterization with detailed chemical sensitivity.

In this contribution, we demonstrate how DNP-enhanced ^{13}C NMR can be applied to analyze two classes of chemically modified celluloses: dialcohol cellulose and cellulose ethers.

For dialcohol cellulose, produced via periodate oxidation and borohydride reduction, DNP-enhanced multiple-contact cross polarization experiments enable quantification of the degree of modification within 20 minutes. Enhancements above a factor of 50 were achieved. Additionally, ^{13}C-^{13}C dipolar recoupling experiments provide chemical shift correlations that reflect the altered ring structure following C2–C3 cleavage.

In a separate study of ethyl hydroxyethyl cellulose (EHEC) and methyl ethyl hydroxyethyl cellulose (MEHEC), we employed selective *J*-coupling-based polarization transfer to quantify substitution at the C2 position. The method is compatible with partially deuterated aqueous solvents, enabling homogeneous swelling and uniform DNP enhancement of these hydrophilic systems, with signal enhancements exceeding a factor of 100. Preliminary results also indicate potential for resolving substitution at C3, which would allow more complete profiling of substitution patterns.

By combining high sensitivity with atomic-level resolution, DNP-enhanced solid-state NMR offers a robust analytical approach for mapping chemical heterogeneity in cellulose derivatives. These studies highlight its relevance for both fundamental structure elucidation and the development of advanced polysaccharide-based materials.

[1] Karlsson, K.; Svenningsson, L.; Storm, R.; Chaiyupatham, P.; Brolin, A.; Larsson, A.; Pinon, A.C.; Schantz, S.; Karlson, L.; Larsson, P.A.; Evenäs, L., *Cellulose* **2024**, 31 10727-10744

O13.2 - STRUCTURAL ANALYSIS OF DIFFERENT BACTERIAL FRUCTANS

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

StructurAL ANALYSIS of different bacterial fructans

Ernst, L.*[a], Härer, L.[b], Offermann, H. [a], Werner, A.[a], Grafe, F. [a], Huisinga, R. [a], Stadler, F. [a], Puchalla, N.[a], Bechtner, J.[c], Ehrmann, M.[b], Wefers, D.[a]

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Several lactic and acetic acid bacteria encode fructansucrases (GH family 68) which catalyze the polymerization of fructans from sucrose. Depending on the type of their backbone linkage, these fructans can be classified as inulins (β-2,1-Fru*f*) and levans (β-2,6-Fru*f*). The two types can be branched at positions *O*6 or *O*1, respectively, and have rather high molecular weights compared to fructans from plants. Despite the comparably simple synthesis by microorganisms or recombinant fructansucrases as well as a possible *in situ* formation in food, the potential of bacterial fructans for medical or food applications is far from being fully exploited. Although the physicochemical properties and thus the applicability of bacterial fructans is highly depended on their molecular structure, studies focused on the detailed structural analysis are scarce. Furthermore, it is difficult to compare the results from different studies due to different analytical methods used.

Therefore, the aim of this study was to analyze and compare the fine structures of various enzymatically or fermentatively synthesized bacterial fructans. ^{1}H-NMR spectroscopy as well as methylation analysis with conditions adjusted for fructans [1] was used to assess the fructan type as well as the degree of branching. Furthermore, different recombinant *endo*-levanases and *endo*-inulinases were produced and used to partially hydrolyze the fructans. The liberated oligo- and polysaccharides were analyzed by high-performance anion exchange chromatography with pulsed amperometric and mass spectrometric detection as well as size exclusion chromatography with refractive index detection. The degrees of branching of different fructans showed significant variation and ranged between 7 and 25 %. Notably, fermentatively produced levans had a higher diversity than the enzymatically synthesized inulins. Furthermore, the formation of bacterial fructans with 2,1- as well as 2,6-linkages could be characterized for the first time. Several linear and branched oligosaccharides were released by the partial enzymatic hydrolyses. Although some oligosaccharide structures are yet unknown, the peak profiles in the hydrolysates suggested varying accessibility and complex structural architectures. In addition, the partial hydrolysis of the mixed-linkage fructans suggested that they are copolymers composed of inulin and levan sections. Furthermore, we were able to demonstrate that bacterial fructans have varying molecular weights which were in the range of several million Dalton.

Altogether, the results emphasize that bacterial fructans have a high structural diversity. The elucidation of their fine structures as well as the relationship between conditions during enzymatic synthesis and molecular structure could provide for optimizing production processes and tailoring polysaccharide properties for specific applications.

[1] Ernst, L.; Werner, A.; Wefers, D., *Carbohydr. Polym.* **2023**, *308*, 120643

O13.3 - Analytical approaches to assess the structural complexity of alpha-glucans

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Analytical approaches to assess THE STRUCTURAL COMPLEXITY OF Alpha-glucans

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Different lactic acid bacteria as well as enzymes from the glycoside hydrolase family GH70 can be used to form a wide range of α-glucans from sucrose or starch. These polysaccharides exhibit remarkably complex molecular structures with different molecular weights, different linkages and linkage distributions in the backbone, as well as side chains of varying lengths attached at different positions of the backbone. The molecular structure of α-glucans is most frequently analyzed by ^{1}H NMR spectroscopy. Although this method allows for a basic assessment of the linkages present, it cannot distinguish some structural elements. Methylation analysis can provide a robust overview of the glycosidic linkages; therefore, this approach is more suitable. However, methylation analysis requires a complicated and laborious sample workup, furthermore, it does not yield information on the distribution and length of side chains or on other structural details. This limitation can be overcome by applying approaches based on partial enzymatic hydrolysis of the α-glucans.

Therefore, this approach was used to characterize structurally diverse α-glucans produced by recombinant enzymes or lactic acid bacteria. Dextrans, the most common bacterial α-glucans, were hydrolyzed by using endo-dextranase which allowed for the liberation of several branched oligosaccharides besides glucose and isomaltose. The isolation and structural characterization of these compounds as well as the HPAEC-PAD analysis of their abundance provided detailed information on side chain type, length, and distribution. Furthermore, it was possible to determine the monosaccharide units present at the reducing end after reduction and enzymatic hydrolysis. Significant differences were observed for different dextrans depending on the incubation conditions. For α-glucans with additional linkage types in the backbone, the application of other endo-acting enzymes can provide detailed insights into the occurrence and size of blocks containing distinct glycosidic linkages in the backbone. Furthermore, information on the branching patterns of the individual blocks can be obtained. For isomalto/malto-polysaccharides, which are formed by 4,6-α-glucanotransferases, HPAEC-PAD analysis before and after partial hydrolysis with amylolytic enzymes can yield detailed insights into the structural architecture of these polysaccharides. The approaches described can be used to analyze the structure of diverse α-glucans in a comparably short time, while they also allow for the assessment of structural details. Therefore, they have the potential to be used to guide the production of tailored α-glucans for different applications.

Parallel session 14 - Biomedical & Well-Being Applications

2025-08-26
11:30 - 12:30
Parallel session 14 - Biomedical & Well-Being Applications

O14.1 - SURFACE MODIFICATION OF POLYCAPROLACTONE 3D SCAFFOLDS USING HYALURONIC ACID-GLYCINE PEPTIDE CONJUGATES TO ENHANCE ENDOTHELIAL CELL ADHESION

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

Surface Modification of Polycaprolactone 3D Scaffolds Using Hyaluronic Acid-Glycine Peptide Conjugates to Enhance Endothelial Cell Adhesion

Mohan, T.[a], Gürer, F[b], Kargl, R.[a], Gradišnik, L.[c], Maver, U.[c], Stana Kleinschek, K[*a]

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[b]Laboratory for Characterisation and Processing of Polymers, Faculty of Mechanical Engineering, University of Maribor, Slovenia

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Enhancing the bioactivity of polycaprolactone (PCL) scaffolds is essential for advancing tissue engineering applications. This study explores the functionalization of 3D-printed PCL scaffolds with hyaluronic acid glycine-peptide conjugates to improve endothelial cell adhesion and growth. Known for its biocompatibility and cell-supportive properties, hyaluronic acid was conjugated with a glycine-peptide to form a bioactive interface on the PCL scaffolds. These scaffolds were fabricated using a melt extrusion 3D printing technique. The HA-glycine peptide conjugates were oxidized with sodium periodate and then immobilized onto aminolyzed PCL scaffolds via Schiff-base chemistry. This functionalization introduced hydrophilicity, multiple functional groups (amine, carboxyl, amide, imine), and a negative zeta potential. Remarkably, the functionalized scaffolds exhibited a two-fold increase in mechanical properties compared to the control samples. In vitro experiments revealed a significant enhancement in human endothelial cell adhesion, proliferation, and viability on the functionalized scaffolds compared to the non-functionalized ones. These findings suggest that HA-glycine-peptide conjugation effectively improves endothelialization of PCL scaffolds, offering a promising strategy for developing vascularized tissue constructs in regenerative medicine[1].

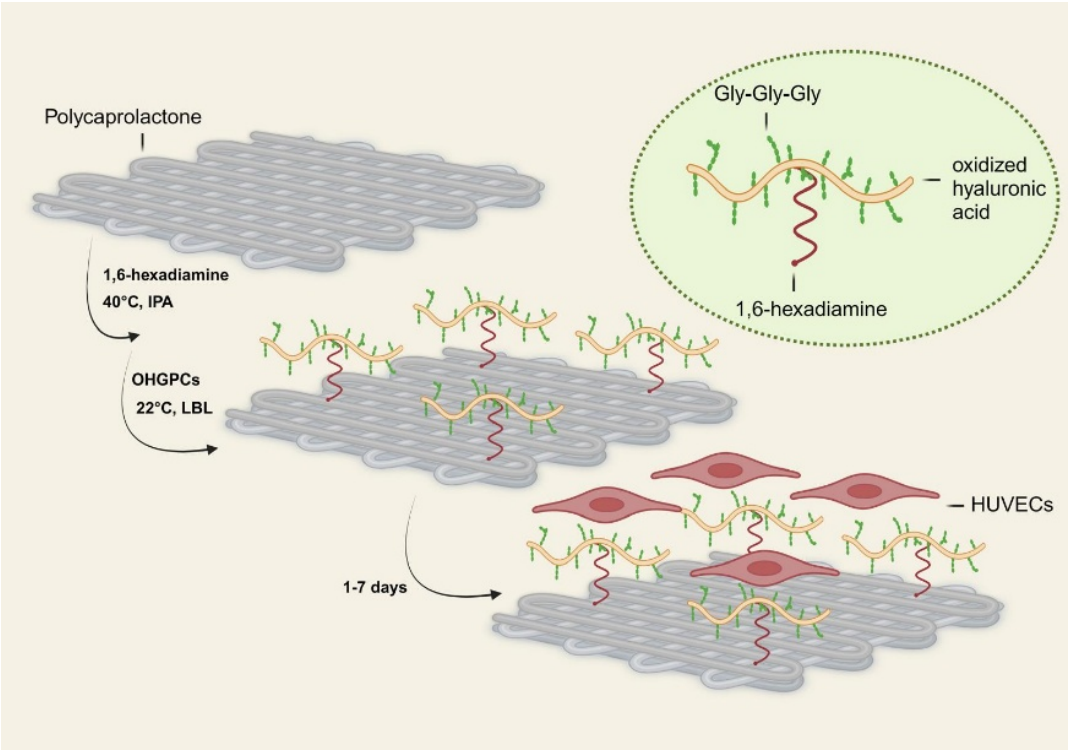

Figure 1. Diagram showing the conjugation of oxidized hyaluronic acid glycine–peptide conjugates (OHAGPCs) to aminolyzed PCL scaffold and their effect on endothelial cell adhesion.

[1] Mohan, T.; Gürer, F.; Bračič, D.; Lackner, F.; Nagaraj, C.; Maver, U.; Gradišnik, L.; Finšgar, M.; Kargl, R.; Kleinschek, K. S. *Biomacromolecules* **2025**, *26*, 1771.

O14.2 - Photocurable cellulose nanofiber and its hybrid copolymerized with polyacrylamide for 3D cell culture: synthesis and microgel strategy

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

photocurable cellulose nanofiber and its hybrid copolymerized with polyacrylamide for 3D cell culture: SYNTHESIS AND MICROGEL STRATEGY

Liang, S.[a, b], Xu, C.[b], Wang, X.*[a, b]

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[b] Laboratory of Natural Materials Technology, Faculty of Science and Engineering, Åbo Akademi University, Finland

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Cellulose nanofibers (CNFs) are sustainable nanomaterials that form hydrogel networks at low concentrations (<1 wt%), mimicking the extracellular matrix (ECM) for 3D cell cultivation. Significantly, the matrix stiffness and elasticity are import biomechanical cues to regulate the cellullar responses to the microenviorment in 3D cell culture. Pristine CNF hydrogels are typically limited by weak ionic crosslinking, thus poor in biomechanical tunability. In our earlier report [1], we have established the synthetic chemistry for yielding the methacrylated cellulose nanofiber (CNFMA) with anionic surface charge of -COO^- as well as have validated the photopolymerizable reactivity of CNFMA as solely nanocellulose or copolymerized with acrylamide (AA). The *in-situ* copolymerization of to form covalently bonded but interpenetrated network of cellulose nanofibril and CNFMA and polyacrylamide (PAA) in the hybrid, which offers means of modulation to the matrix stiffness. Moreover, creating macroporosity within the hydrogel system is essential for the accommodated living cells as it is demanded for efficient nutrient transportation and cell infiltration throughout 3D matrix. In the newest advancement of our research line, we have created microgels of CNF and its hybrid, as well as further validated the use of these 3D nanomaterial network as granular assembly hydrogel in the workflow of 3D cell culture. Our microgel fabrication has leveraged the dual crosslinking mechanism associated with CNFMA—photocuring and Ca^{2+}-mediated ionic bonding. Microgels of CNFMA and its hybrid were produced by mechanically sieving photocured bulk hydrogels. The reassembling of granular hydrogels with laden cells offer with customizable stiffness and macroporosity, improving cell-matrix interactions and infiltration. We validated this platform with pre-osteoblasts (MC3T3-E1) and pancreatic cancer cells (PANC-1). The stiffness heterogeneity present in the hybrid network of CNFMA-PAA network's enhanced cytoskeletal tension in MC3T3-E1 and induced spheroid formation and lamellar morphologies in PANC-1, showcasing cell-specific biomechanical responses.

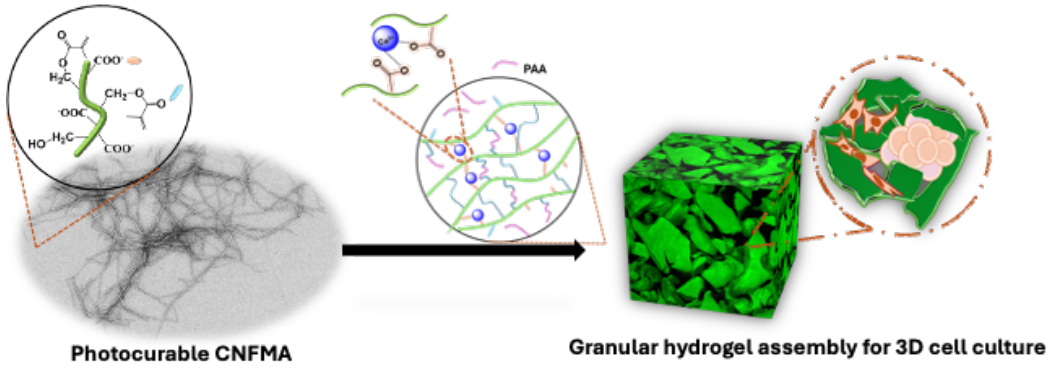

Figure 1. Microgel strategy for 3D cell culture facilitated by dual-crosslinkable CNFMA

[1] Brusentsev, Y.; Yang, P.; King, A.W.; Cheng, F.; Cortes Ruiz, M.F.; Eriksson, J.E.; Kilpeläinen, I.; Willför, S.; Xu, C.; Wågberg, L.; Wang, X., Biomacromol. 2023, 24(8), 3835-3845.

O14.3 - Cellulose nanofiber scaffolds with surface carboxy groups for stem cell modulation

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

Cellulose Nanofiber Scaffolds with Surface

Carboxy Groups for Stem Cell Modulation

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The development of cell culture scaffolds that emulate the extracellular matrix (ECM) is crucial for facilitating cell growth and development. In this study, cellulose nanofibers (CNFs) derived from wood were used to mimic the fibrous structures of collagen and elastin (Figure 1a). Carboxy groups were introduced to the CNFs by TEMPO oxidation to imitate the structure of uronic acid [1]. Mesenchymal stem cells (MSCs) were cultured on a scaffold composed of TEMPO-oxidized cellulose nanofibers (TOCNF) with different carboxy content, fiber lengths, and altered crystalline structures. The amount of carboxy groups was adjusted by varying the sodium hypochlorite added. In cell culture experiments, MSCs from human bone marrow origin were used to investigate cell adhesion, proliferation, and gene expression. On unmodified CNF scaffolds, cells formed spheroids, while on TOCNF scaffolds, cells adhered, elongated, and proliferated. Short TOCNF fibers allowed faster cell elongation and better growth (Figure 1b). Notably, even when the appropriate amount of carboxy groups was introduced, the cells did not adhere to TOCNF that had a cellulose II crystal structure due to the mercerization. MSCs seeded on various scaffolds, with or without adhesion proteins, exhibited rapid adhesion and spreading on short TOCNFs, even in the absence of adhesion proteins. Furthermore, primary MSCs exhibited enhanced proliferation on TOCNF scaffolds compared to polystyrene ones. These findings underscore the significant potential of wood-derived nanocellulose scaffolds as a platform for large-scale culturing of MSCs in regenerative medicine.

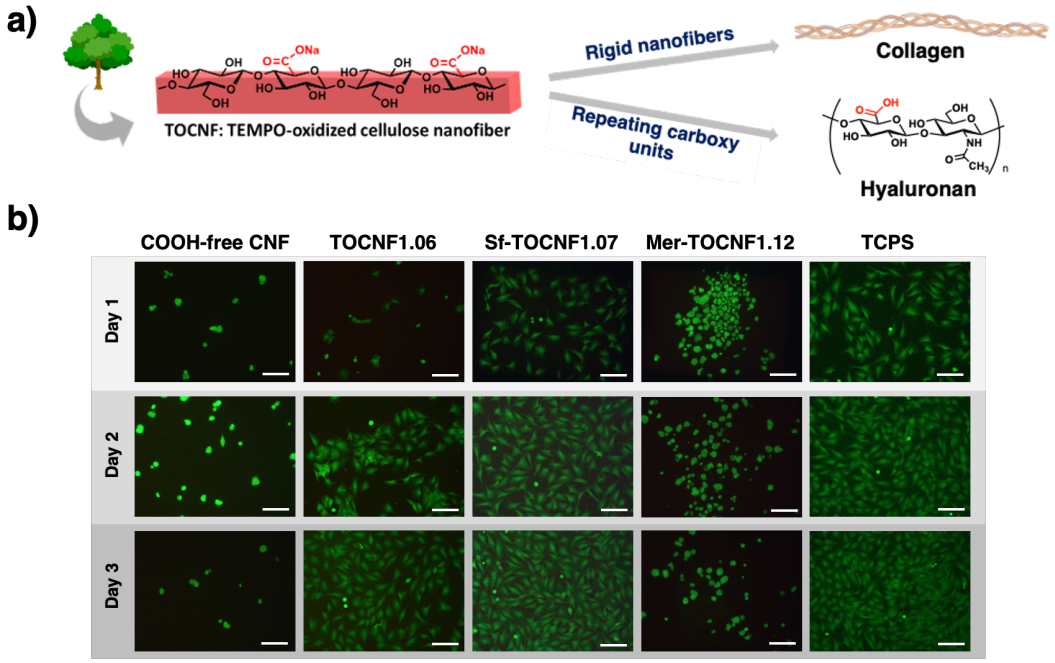

Figure 1. The strategy of this study (a) and the morphology of MSCs cultured on TOCNF scaffolds (b). The indexed values in the sample names indicate the amount of carboxy groups, where Sf means short fiber, and Mer means mercerized. TCPS: tissue culture polystyrene. Live cells: green, dead cells: red, scale bars: 200 µm.

[1] Hatakeyama, M. & Kitaoka, T., *Cellulose* **2022**, *29*, 2869–2883

Parallel session 15 - Materials & Engineering

2025-08-26
11:30 - 12:30
Parallel session 15 - Materials & Engineering

O15.1 - SUSTAINABLE APPROACH FOR THE MULTIFUNCTIONALIZATION OF STARCH BASED FILMS FOR PACKAGING APPLICATIONS

Textile, Pulp, Paper & Packaging
Materials & Engineering

sustainable approach for the multifunctionalization of starch based films for packaging applications

Gerigk, Y., Silva, J.M., Vilela, C., Silvestre, A.J.D., Freire, C.S.R.*

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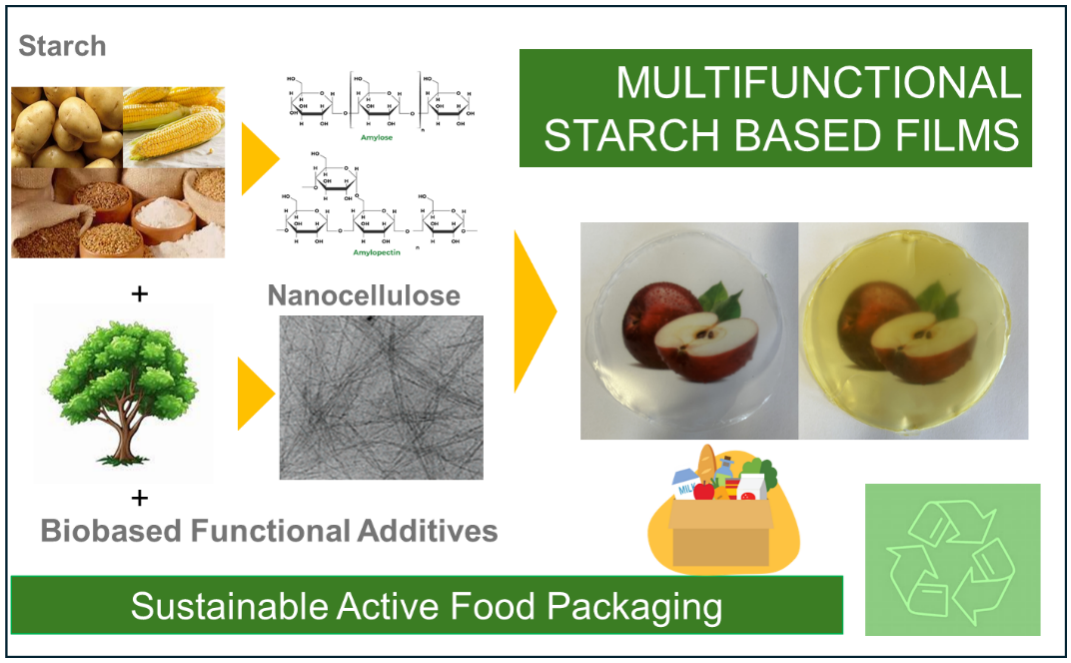
The use of biopolymeric materials and active packaging technologies are among the emerging tendencies for the implementation of sustainability and circularity in the food packaging industry. Within the plethora of biopolymers, starch is documented as one of the most promising to be exploited in this sector since it is fully biodegradable, non-toxic, abundant, and has the ability to be converted into a bioplastic, viz. thermoplastic starch (TPS). However, TPS films exhibit some weaknesses, namely poor mechanical properties (low tensile strength), high moisture sensitivity and lack of biological functionalities (e.g., antioxidant and antimicrobial properties) that hinder their broader application as a sustainable active packaging material.

In this work, an entirely biobased strategy for the hydrophobization, reinforcement and biological multifunctionalization of TPS films, based on the combination of nanocellulose and biobased active additives was developed and optimized. The detailed characterization of the obtained films and their potential application will be presented and discussed.



[1] H. Cheng et al., *Trends Food Sci.Technol.* **2021**, *114*, 70-82.

Acknowledgments: This work was developed within the scope of the project CICECO-Aveiro Institute of Materials, UIDB/50011/2020 (DOI 10.54499/UIDB/50011/2020), UIDP/50011/2020 (DOI 10.54499/UIDP/50011/2020) & LA/P/0006/2020 (DOI 10.54499/LA/P/0006/2020), financed by national funds through the FCT/MEC (PIDDAC). FCT is acknowledged for the research contracts under Scientific Employment Stimulus to C.S.R.F. (DOI 10.54499/CEECIND/00464/2017/CP1459/CT0033), C.V. (DOI 10.54499/2021.01571.CEECIND/CP1659/CT0024).

O15.2 - BARRIER PROPERTIES OF CELLULOSE DERIVATIVE FILMS FOR FOOD-PACKAGING

Textile, Pulp, Paper & Packaging
Materials & Engineering

Barrier properties of cellulose derivative films for Food-Packaging

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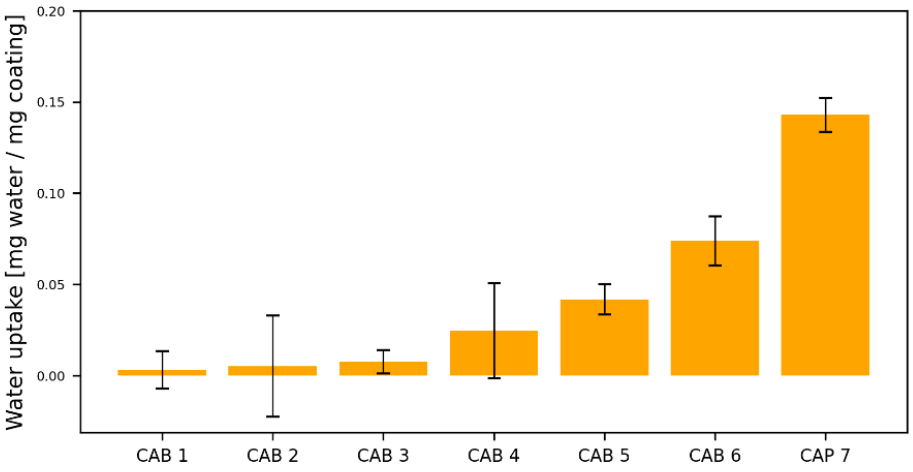
Cellulose-based films can be a sustainable alternative to plastics in food packaging. Due to the hydrophilic nature of cellulose, hydrophobic modification is required to enhance its water-resistant properties. Cellulose esters are promising materials to overcome this challenge, and their tuneable properties facilitate lowering the environmental impact of food packaging.

We investigated the water barrier suitability of seven commercially available cellulose esters (cellulose acetate butyrate (CAB) and cellulose acetate propionate (CAP)) with varying degree- and nature of substitution, and molecular weight. Solvent casted films were examined for water vapor transmission rate (WVTR), water absorption (COBB), and mechanical properties.

The water uptake of ~30 nm thick spin coated films were tested with the D_2O exchange experiment with quartz crystal microbalance with dissipation monitoring (QCM-d). SEM images and AFM images were obtained to visualize the films.

The spin coated cellulose derivative films had generally low swelling compared to cellulose films. Water uptake was related back to the composition of the cellulose derivatives. The lowest water uptake was measured for medium-high molecular weight, highly substituted cellulose derivatives with values lower than 0.04 mg water per mg coating (CAB 1, CAB 2, CAB 3). The highest water uptake was measured for the derivative with the shortest substituent (propionyl), highest OH content, and lowest molecular weight (CAP 7).

These findings suggest that cellulose derivatives show promise as an alternative to fossil-plastics as barriers in food packaging.



Butyryl / Propionyl (P) High High Low Low Low Med Med (P)

Acetyl Low Low High High High Low Low

Molecular weight Med High High Med Low Low Low

Figure 1: Water uptake of cellulose derivatives from D_2O exchange QCM-d measurements.

O15.3 - MULTILAYER BIOBASED PACKAGING FILMS BASED ON NANOCELLULOSES FROM FOOD INDUSTRY BY-PRODUCTS

Textile, Pulp, Paper & Packaging
Materials & Engineering

Multilayer biobased packaging films based on nanocelluloses from food industry by-products

Jingwen Chen [a, b], Chloé Chevigny [a]*, Sandra Domenek [a], Milena Martelli-Tosi [b], Giana Almeida-Perré [a]

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[b]Departamento de Engenharia de Alimentos, Faculdade de Zootecnia e Engenharia de Alimentos, Universidade de São Paulo, Rua Duque de Caxias Norte 225, CEP

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The agri-food industry generates a large quantity of by-products, such as peels and stalks, which still contain bioactive ingredients and lignocellulosic biomass. These residues represent a potential source of active/high value-added compounds, notably cellulose nanofibrils (CNFs), recognized for their excellent oxygen barrier properties. This makes them particularly interesting for food packaging. However, moisture affects these properties, causing nanocelluloses to swell, which greatly reduces their effectiveness.

Our recent research has shown that a multi-layer architecture, including a hydrophobic first layer of poly(lactide) (PLA), can protect nanocelluloses from moisture, and thus produce multi-layer materials with an exceptional oxygen barrier [1,2]. This work is an application of these recent results (obtained with "model" and commercial nanocelluloses) on CNFs gently extracted from by-products of the agronomic industry [3] (grape stalks, artichoke stems, coffee grounds), as part of a circular economy approach aimed at creating sustainable food packaging with lower environmental cost.

Nanofibrils are applied to PLA films using a bar coating method to create fully bio-sourced and compostable multilayer films. The structure of these films is analyzed by microscopy (SEM, AFM) and linked to gas permeation and transport properties. The results confirm the suitability of the multilayer architecture for obtaining a good gas barrier, but have also revealed a major influence of the botanical origin and of the CNF production process on these performances. The formulation of these films thus had to be adapted when switching from the "model" system to actual by-products, which variability is much greater.

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Parallel session 16 - Materials & Engineering

2025-08-26
13:50 - 15:10
Parallel session 16 - Materials & Engineering

O16.1 - From Batch to Continuous: Microcrystalline Cellulose Production Using Twin-Screw Extrusion

Sustainable Materials/Circular Economy
Materials & Engineering

From Batch to CONTINUOUS : Microcrystalline Cellulose Production Using Twin-Screw Extrusion

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The industrial production of microcrystalline cellulose (MCC) has traditionally relied on acid hydrolysis in batch reactors, often requiring large volumes of solvent and complex downstream purification. As the demand for sustainable, high-performance biobased materials grows, so does the need to improve the efficiency, scalability, and environmental profile of MCC production.

At Fibenol, we are pioneering a novel solvent-free, continuous process for MCC production using twin-screw extrusion (TSE). This method enables controlled mechanochemical reactions in a neat environment, significantly reducing water usage and eliminating the need for neutralization or solvent recovery. The process design allows tight control over residence time, temperature, and mechanical shear, which are critical for tailoring MCC particle properties.

This contribution presents a comparative study between conventional batch-based hydrolysis and the novel TSE-based continuous process, highlighting differences in energy consumption, material properties, and environmental impact. Initial trials demonstrate that the extruded MCC exhibits comparable crystallinity and morphology to commercial grades, while offering unique potential for functionalization and integration into thermoformed fiber products.

This work supports the broader shift in green chemistry toward process intensification and showcases the value of adapting industrial biotechnology to modern continuous manufacturing platforms.

O16.2 - Optimization of Periodate Oxidation Conditions for Cellulose Nanomaterials

Sustainable Materials/Circular Economy
Materials & Engineering

Optimization of Periodate Oxidation Conditions for Cellulose Nanomaterials

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Periodate oxidation of cellulose breaks the C2–C3 bond of the glucose repeating units, forming two vicinal aldehyde groups that can be used for further reactions. In this study, we examined how the different types of nanocellulose influence the oxidation reaction. The oxidation of three types of nanocellulose, such as cellulose nanocrystals (CNC), cellulose nanofibers (CNF), and bacterial nanocellulose (BNC), was compared. For each type of matrix, the effect of reaction conditions (such as reaction time, oxidant amount, and temperature) on the aldehyde content and crystallinity were investigated. Moreover, optimized reaction conditions for all three nanomaterials were identified. The presence of 2,3-dialdehyde groups on cellulose (DAC) was confirmed by Fourier-transform infrared spectroscopy (FTIR), and the aldehyde content was quantified by titration. The crystallinity of the oxidized cellulose was determined by wide-angle X-ray scattering, as shown in Figure 1, which shows that the crystallinity decreases as the degree of oxidation increases. This study provides insights into tailoring oxidation conditions based on the nanocellulose matrix, facilitating their further functionalization for diverse applications.

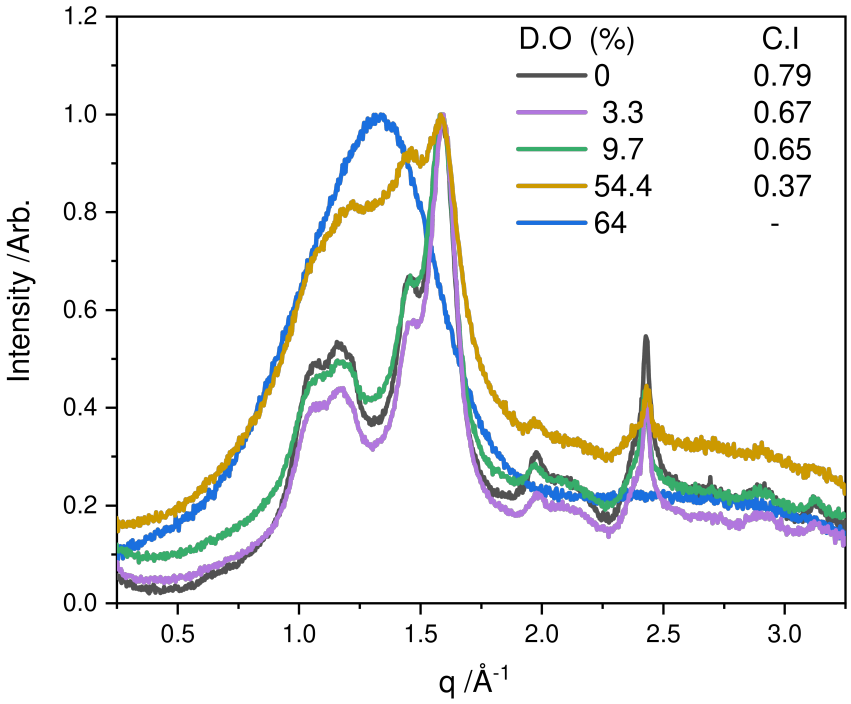

Figure 2 **Figure 1 : WAXS analysis showing the decrease in crystallinity with increasing oxidation of nanocellulose**

O16.3 - NEXT-GENERATION ELASTOMERIC MATERIALS FROM BIOPOLYMERIC NANOFIBROUS BLENDS: UNLOCKING SUSTAINABILITY USING POLYSACCHARIDES

Sustainable Materials/Circular Economy
Materials & Engineering

Next-generation elastomeric materials from biopolymeric nanofibrous blends: unlocking sustainability using polysaccharides

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Sustainability goals, particularly the adoption of advanced bio-based materials as alternatives to petroleum-derived counterparts, are gaining significant momentum, fostering innovations across various sectors such as textiles, wearable sensors, agro-industry, food technology, and biomedical materials. However, the field of highly elastic (elastomeric) materials still lacks a fully biobased product with high biodegradability potential. Here we present the key to unlocking sustainability into this field by introducing biobased nano and microfibers from blends of renewable polymers, including the most abundant cellulose and its derivatives [1]. By manipulating the morphology of fibrous entities and their form (non-woven or yarns), we can tune the elasticity of novel materials, with mechanical behavior that complies with standard hyperelastic models. Exceptional values of strains ranging from 100-1000% match conventional rubber products, but further combined with preserved biodegradation obtained for these novel materials, represent a significant step beyond traditional vulcanized rubber of low biodegradation potential. In this manner, we pave the way for reducing the environmental impact of rubber waste in the future.

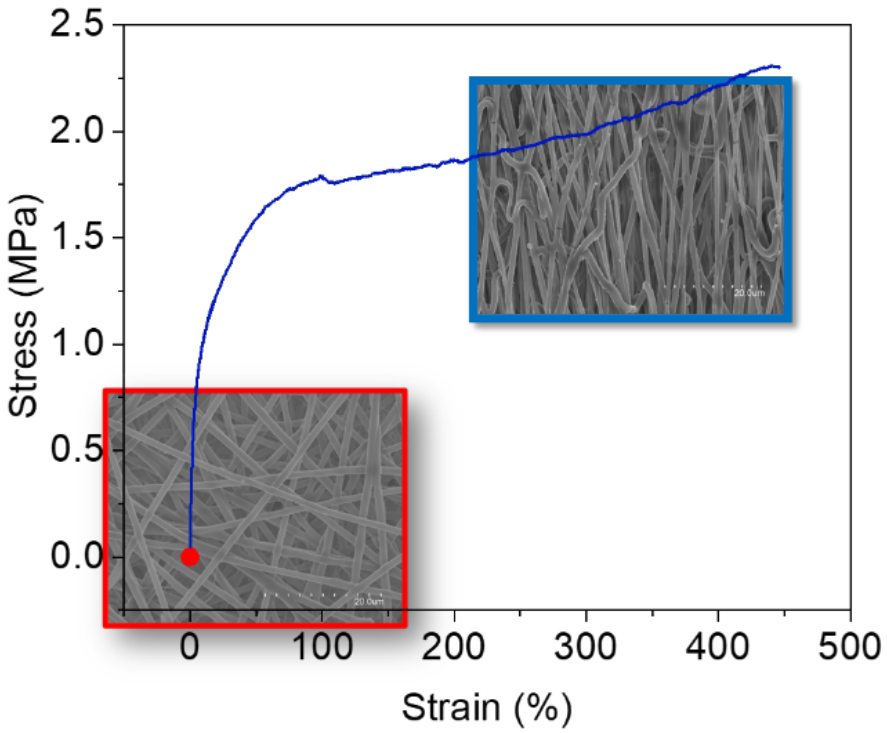

Figure 1. Representative stress-strain curve and SEM images before and during stretching

Acknowledgement: This study is supported by the Agencia Valenciana de Innovación (AVI), project INNEST/2022/25, the Spanish Ministry of Science Innovation and Universities (MCIU), project PID2021-128749OB-C31, the Unidad Asociada IATA(CSIC)-UJI in "Polymer Technology", CSIC-PTI SusPlast and the Accreditation as Center of Excellence Severo Ochoa CEX2021-001189-S funded by MCIU/AEI/10.13039/501100011033 and Horizon Europe EU 4 Health Project No. 101203379 ¨2G-Proveil¨.

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O16.4 - Optimizing the Mechanical Properties of Cellulosic Foams through Fiber Dimensions

Sustainable Materials/Circular Economy
Materials & Engineering

Optimizing the Mechanical Properties of Cellulosic Foams through Fiber Dimensions

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Conventional petroleum-based foams, mainly polyethylene (PE) and polyurethane (PU), are currently used to protect various materials during storage and transportation of cultural artifacts. Although these foams are lightweight, cost effective, water resistant, and have excellent shock absorption and compressive strength, their petroleum origin and difficult recycling are an environmental concern. This research aims to investigate an alternative foam made on cellulosic fibers.

Cellulose fibers are a promising precursor for synthetizing cushioning foams due to their structure and biosourced nature. We studied the influence of cellulose fiber dimensions and concentration on the morphology, density, and mechanical properties of cellulose-based foams. Five types of fibers were selected, with lengths ranging from 200 µm to 2 mm, and diameter between 20 and 40 µm. The rheological properties of fiber dispersions were assessed using an oscillatory strain sweep test. All fiber dispersions exhibited viscoelastic solid behavior, with pronounced fiber-fiber interactions even at low concentration. The elasticity of the dispersions increased with fiber concentration and fiber length. Subsequently, foams were synthesized using the foam-forming method[1] (Fig. 1), an environmentally friendly technique preferred over more energy-intensive methods such as lyophilization and supercritical drying. The densities achieved ranged from 15 $gL^{-1}$to over 100 gL^{-1},

similar to the ranges of PE and PU foams commonly used for cushioning. The foam density was directly linked to fibers concentration in the initial dispersion. The compressive strength of foam was measured by compressing them to 50% of their initial height. Results indicated that compressive stress increased with foam density and fiber length. At a density of 30 gL^{-1}, cellulose foams exhibited compressive stress values ranging from 5 to 20 kPa, comparable to soft PU foams (7 kPa).

C

D

B

A

Fig. 1 : cellulose foams obtained from fibers of different average sizes: A) Length ≈ 2 mm / diameter = 40 µm, B) Length = 700 µm ; diameter = 20 µm, C) Length = 500 µm ; diameter = 25 µm, D) Length = 300 µm ; diameter = 20 µm.

These attempts to produce foams using a foam-forming technique with cellulose fibers are promising alternatives to replace PE and PU foams; physical and chemical behavior of these foams are currently evaluated.

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Parallel session 17 - Food & Nutrition

2025-08-26
13:50 - 14:50
Parallel session 17 - Food & Nutrition

O17.1 - Microwave assisted extraction of citrus pectins towards edible coatings

Sustainable Materials/Circular Economy
Materials & Engineering

Microwave assisted extraction of citrus pectins towards edible coatings

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Pectin is an abundant, complex, and versatile polysaccharide with wide-ranging applications in the food and pharmaceutical sectors, primarily due to its gelling, thickening, and stabilizing properties [1]. In recent years, special attention has been given to its role as a dietary fiber, supporting the immune barrier and promoting a beneficial gut microbiome [2]. Thanks to its biocompatibility and biodegradability, pectin is also a promising natural polymer for use in edible coatings, contributing to extended shelf-life of food products. In this study, pectins were recovered from citrus peels—including orange, lemon, and lime—using microwave-assisted extraction (MAE) as a green extraction technique. The influence of different extraction parameters in terms of time (5, 10, and 15 min) as well as temperature (140, 160, and 180 °C) on the structure and functionality of the recovered polysaccharides were evaluated. The extracted pectins were characterized by their molar mass, carbohydrate profile, and phenolic content. The extraction yield ranged from 3.59 to 44.45 % with the change of variables and type of biomass. Molar mass of the obtained pectins were superior to 10^6 Da. Structurally, orange and lime pectins were dominated by the homogalacturonan (HG) domain, with an increasing presence of the rhamnogalacturonan I (RG-I) domain as extraction time increased at 140°C and 160°C. In contrast, lemon pectin showed no significant variation in HG and RG-I content until 180°C, where RG-I became more prominent in relation to HG with extended extraction times. Total phenolic composition of pectins shows that 1.10-7.90 mg GAE.g^{-1} for orange, 2.68-10.92 mg GAE.g^{-1} for lemon, and 0.87-4.95 mg GAE.g^{-1} for lime pectins, tending to increase with the extraction temperature. The total phenolic content ranged from 1.10–7.90 mg GAE·g^{-1} for orange, 2.68–10.92 mg GAE·g^{-1} for lemon, and 0.87–4.95 mg GAE·g^{-1} for lime pectins, increasing as well with temperature. HPLC-DAD analysis identified the major bound phenolic compounds in the extracted pectins as ferulic acid (orange), sinapic acid (lemon), and coumaric acid (lime), indicating a biomass-dependent phenolic profile. The presence of these phenolic is directly related to the antioxidant properties of the bio-based fibers. The results revealed the potential of the extraction technique on the recovery of agro-industrial by-products polysaccharides, which can be fine-tuned to improve the recovery yields and the functionality of the target molecules for further applications in functional packaging materials.

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O17.2 - GREEN STRATEGY FOR PECTIN EXTRACTION: COMBINING GRINDING WITH DEEP EUTECTIC SOLVENTS

Extraction & Purification
Chemistry, Biology & Physics

Green strategy for pectin extraction: combining grinding with deep eutectic solvents

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Pectins are polysaccharides widely used as gelling, thickening, or emulsifying agent in food industry. In other sectors, such as pharmaceuticals or healthcare, their ability to form physical hydrogels is also exploited to manufacture matrices for encapsulating active components (Munarin et al., 2012). Typically, pectins are extracted from food co-products such as lemon peels or apple pomace through acidic extraction, achieving mass yield around 20% (Kumar & Chauhan, 2010). However, these harsh conditions generate large volumes of effluents and can degrade pectin structure. This study explores a greener alternative extraction method combining ball milling and deep eutectic solvents (DES) for the selective extraction of pectin from lemon peels or apple pomace, preserving its structure for optimal gelation performance. Three DES systems with similar polarity but differing in chemical structure, interaction potential, and viscosity were investigated. For apple pomace, extraction yields were higher with both the chloride:lactic acid and the hydrated choline chloride:malic acid DES, whereas lemon peels gave higher yields with the hydrated choline chloride:malic acid system.

The mass yield obtained when combining grinding with deep eutectic solvents (DES) was twice as high as that from DES extraction under stirring alone at identical initial particle size. This indicates that the disruption generated by grinding enhances extraction beyond simply increasing cell wall accessibility (Rajaonarivony et al., 2019). Its action, combined with that of DES, promotes the release of polysaccharide through localised energy dissipation and heating, which favours the cleavage of structural molecular bonds within the biomass, ultimately leading to higher yields. A stronger effect of grinding was also observed for lemon peels. These differences likely stem from biomass processing history: lemon peels, simply dried after peeling, retain mostly intact tissues, making them more susceptible to grinding and facilitating extraction. In contrast, apple pomace

undergoes crushing and pressing, which partially disrupts its tissues and reduces the impact of grinding during extraction.

Acknowledgments

The PLANET facility (https://doi.org/10.15454/1.5572338990609338E12) run by the IATE joint research unit for providing process experiment supports. The University of Montpellier, the International Associated Lab BIOMATA and Agropolis Fondation for financially supporting this research work.

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O17.3 - WAVEPURE®, A LABEL-FRIENDLY SEAWEED POWDER FOR FOOD, FEED, AND COSMETIC APPLICATIONS: CHALLENGES AND OPPORTUNITIES

Food Additives, Consistency & Texture
Food & Nutrition

WavePure®, a label-friendly seaweed powder for food, feed, and cosmetic applications: Challenges and Opportunities.

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The negative consumer perception of highly transformed additives and ingredients push the whole industry to rethink its traditional approach and to pivot towards the development of low-processed additives and ingredients [1]. In parallel with this trend, a better valorisation of the marine biomass seems to be essential to overcome the future challenges of the humanity regarding the demography and the preservation of arable land for agriculture.

In this context Cargill launched WavePure®, a brand of label-friendly seaweed powders which are produced without chemical modification from *Gracilaria, Kappaphycus,* and/or *Eucheuma Denticulatum* (Figure 1). Developing such ingredients combining consumers' expectations, customers' requests and regulatory constraints opens promising opportunities but required also to overcome several challenges such as color, taste, etc.

Initially the seaweed powders that Cargill developed and for which it was awarded with a patent [2] via WavePure® brand were focused in dairy and dairy alternative categories due to the great body and consistent mouthfeel that they bring. However, the seaweed powders can be also interesting in other categories than dairy: beverage, glazing, water-jelly (with and without sugar), etc. Today, WavePure® brand is growing offering great texture that we can transpose in multiple categories in food, feed, and cosmetic applications.

Figure 1. WavePure® is made using clean processing & technology

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Parallel session 18 - Chemistry, Biology & Physics

2025-08-26
13:50 - 15:10
Parallel session 18 - Chemistry, Biology & Physics

O18.1 - APPLICATION OF MACHINE LEARNING IN NANOCELLULOSE ASSESSMENT: STREAMLINING SEDIMENTATION TESTING FOR SURFACE AREA EVALUATION

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Application of Machine Learning in Nanocellulose Assessment: Streamlining Sedimentation Testing for Surface Area Evaluation

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Cellulose nanofibers (CNF) derived from renewable plant biomass, has attracted considerable attention owing to its exceptional lightweight and high-strength properties, making it an ideal reinforcing filler for composite materials. The specific surface area (SSA) of CNF plays an important role in determining the mechanical properties and formability of resin composites, necessitating rapid and accurate morphological characterization. Sedimentation testing provides a fast method to assess CNF morphology, but conventional sedimentation methods have limitations in both accuracy and accessibility. In this study, we present an advanced methodology that combines sedimentation testing with machine learning (ML) techniques [1,2] to predict the SSA of CNF with high precision, thereby enhancing the efficiency of morphological analysis. We demonstrated two predictive models: one using sedimentation rates with gradient boosting regression for SSA estimation, and another analyzing sedimentation profile heatmaps with convolutional neural networks. Both models achieved high predictive accuracy, with R^2 values reaching up to 0.94, thereby validating their utility for morphological evaluation. Moreover, to substantiate the practical relevance of our approach, we combined the predicted SSA with CNF infrared spectral data to estimate the impact strength of polypropylene/lignocellulose composites. This integrated data approach achieved an R^2 of 0.88 in predicting impact strength, underscoring the effectiveness of SSA prediction in evaluating composite performance. In conclusion, this sedimentation-based analysis method provides a straightforward and reliable way to obtain CNF morphology data, offering significant benefits for CNF quality control and material development. Additionally, this presentation introduces efforts to reduce the 24-hour data acquisition time. This approach holds broad potential for improving CNF-reinforced composites, supporting advances in research and industrial applications focused on enhanced material performance and sustainability.

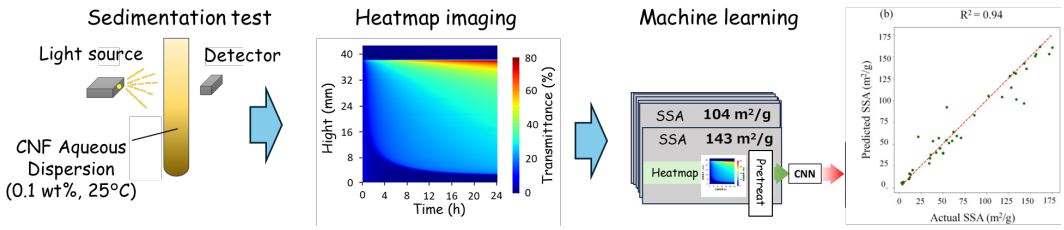

Figure. Scheme of the Machine Learning Model for CNF SSA Prediction

Acknowledgement

This work was supported by Grant-in-Aid for Early-Career Scientists Number JP23K13785.

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O18.2 - TEMPO-CATALYZED OXIDATION OF ALKALI-TREATED CELLULOSE SAMPLES

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

TEMPO-catalyzed oxidation of alkali-treated cellulose samples

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TEMPO-catalyzed oxidation of polysaccharides is known as position-selective conversion of C6-primary hydroxy groups to sodium C6-carboxylate group under aqueous and moderate conditions. However, oxidative cleavages and/or β-elimination of glycosidic bonds are unavoidable and are often cause substantial reduction in degree of polymerization (DP) of the oxidized products. This study investigated detailed chemical structure and molar masses/molar mass distributions of water-soluble or water-insoluble TEMPO-oxidized products prepared from 20% (w/w) NaOH-treated (or mercerized) cellulose samples. Bacterial cellulose, and cotton lint and ramie cellulose fibers were soaked in 20% (w/w) NaOH solution followed by washing with water, and the alkali-treated cellulose samples used as either freeze-dried or never-dried cellulose samples were used as starting materials. The mass recovery ratios of the water-soluble fractions were more than 90%, and higher than those prepared from freeze-dried cellulose samples. The solid-state ^{13}C CP/MAS NMR of the oxidized products revealed the clear signals of hydrates/hemiacetals originating from C2/C3-ketones were detected, other than the formation of C6-carboxy groups. The oxidation occurred not only C6-OH groups but with also some of the C2/C3-OH groups under the condition to prepared water-soluble oxidized products from alkali-treated cellulose samples used in this study. These C2/C3-hydrates/hemiacetals were reduced to C2/C3-OH groups with a relatively large amount of $NaBH_4$ in water. There were no carbon signals owing to the C=C bonds in the NMR spectra, indicating that β-elimination little occurred on the oxidized cellulose molecules. SEC/MALLS/RI (size-exclusion chromatography with multi-angle laser-light and refractive index detectors) analysis showed that substantial depolymerization occurred on the oxidized cellulose molecules, showing that the oxidative cleavage of glycosidic bonds with NaOCl/NaOBr are unavoidable during TEMPO-catalyzed oxidation. Although the DP values of the alkali-treated cellulose samples had in the range of 622-1350, those of the water-soluble oxidized products prepared from never-dried alkali-treated cellulose samples decreased to 82-136. The detailed depolymerization mechanism and behavior were studied for the oxidized products at the 25% and 50% NaOH consumptions (from 100% of NaOH consumptions to obtain water-soluble products) during TEMPO-catalyzed oxidation, by NMR and SEC/MALLS/RI analyses. It was found that the C2/C3-ketones were formed only in the water-soluble fractions, but the water-insoluble fraction (partly oxidized products) had no such structures. SEC/MALLS/RI analysis showed that molar masses have bimodal patterns consisting of high and low molar mass fractions. Thus, depolymerization probably occurred on the molecules according to two phases: one is depolymerization of solid cellulose molecules and another is that the water-soluble oxidized products.

O18.3 - Multi-scale characterization of the porosity in pretreated lignocellulosic biomass

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Multi-scale characterization of the porosity in pretreated lignocellulosic biomass

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The transition towards sustainable bio-based processes relies on the efficient conversion of lignocellulosic biomass, a renewable and abundant carbon resource. The biochemical conversion of lignocelluloses into ethanol, through pretreatment, enzymatic hydrolysis and fermentation, has been explored for decades and is nearing maturity. However, hydrolysis remains complex, as its efficiency largely depends on the physico-chemical properties of pretreated biomass. This study develops multi-scale approaches to identify biomass property markers and reactivity, focusing on porous architecture, a key parameter for hydrolysis, as it determines enzyme diffusion before adsorption on cellulose and conversion into glucose. Understanding how porosity influences molecular transport in hydrated biomass is essential for optimizing biomass valorization. We investigate multi-scale porosity in maize stem internodes, considering different genotypes, tissues and pre-treatment conditions [1].

To assess porosity and molecular transport, we use pulsed-field gradient NMR (PFG-NMR) to analyze the diffusion of water and polyethylene glycols (PEGs) probes [2]. Complementary textural analyses, based on adsorption techniques, provide insights into surface properties and pore size distribution. Our results confirm that pretreated samples enhance diffusion, indicating greater cellulosic surface accessibility (fig.1). Diffusion behavior varies with pore structure across tissues, showing clear differences between native and pretreated biomass. It also depends on probe size, revealing mesoporosity's role in enzyme accessibility. By integrating structural imaging techniques, we refine our understanding of cell wall organization [3]. The combined use of diffusion-based and textural characterization provides insights into the structural evolution of lignocellulosic biomass, helping optimize pre-treatment and cultivation strategies for efficient biorefinery processes.

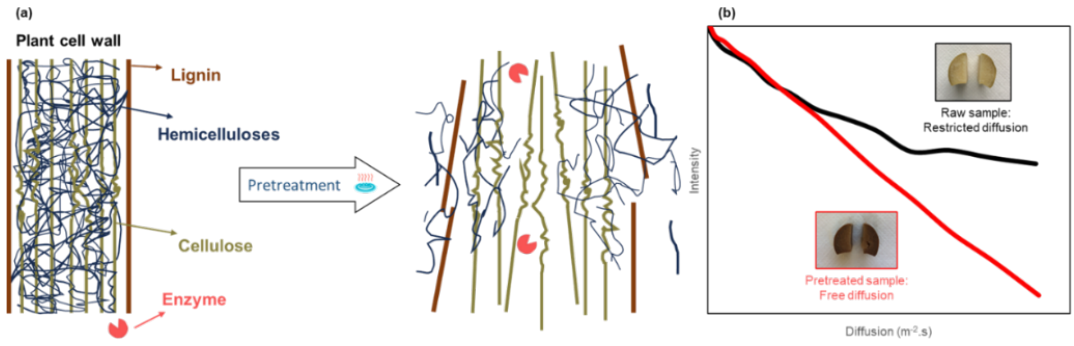

Figure 1. Effect of pretreatment on biomass structure and molecular diffusion. (a) Schematic representation of pretreatment of lignocellulose. (b) PFG-NMR diffusion attenuation of PEG in maize stem.

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O18.4 - WEIGHING POLYSACCHARIDES IN SOLUTION WITH LIGHT USING MASS PHOTOMETRY

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

weighing polysaccharides IN SOLUTION WITH LIGHT using MASS PHOTOMETRY

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Polysaccharides, ubiquitously distributed in the living world, are the most abundant class of biomolecules available on Earth. The vast diversity of sources (plants, algae, animals, bacteria, fungi) and available structures is even enhanced by tailoring new properties from chemical or enzymatic treatments. It is an asset for many applications in various fields, such as biomedical research, cosmetics, food industries, and even battery development.

Determining polysaccharide's molecular weight and structural features is mandatory to correlate their structures with their activities or properties adequately. However, characterising polysaccharides remains challenging due to the great diversity of chemical structures ranging from simple linear homopolymers to branched heteropolymers and their inherent polydispersity. Most of the time, this requires combining multiple analytical techniques, which commonly suffer from significant limitations. For example, NMR requires such a large amount of pure sample and leads to a quite limited resolution, size exclusion chromatography (SEC) exhibits both a limited size range and long elution time, and mass spectrometry (MS) gives only access to relatively low masses and is subject to suppression signal due to high level of salts/buffers/impurities. Moreover, their limited solubility and potential transformations during sample preparation are additional difficulties to their analysis.

Very recently, a new commercially available solution-based analytical tool, Mass Photometry (MP), has been introduced to analyse DNA/RNA, protein complexes, and glycoconjugates at the nanomolar concentration level and in a 30 kDa - 5 MDa range.[1-4] MP is based on the pioneering works from Pr Kukura's group on interferometric scattering (iSCAT) microscopy.[5] MP quantifies light scattered by a single molecule in solution on a glass surface. The amount of light scattered by a particle linearly scales with the particle's volume and refractive index, and then for each molecule is directly correlated to its molecular mass.

Here, we present results from the MP analysis of various polysaccharides from vegetal, animal, and bacterial sources. We demonstrated that MP could be a complementary tool, overcoming some bottlenecks encountered with other analytical methods. Then MP provides a simple, easy-to-use

technology enabling a very fast and accurate polysaccharide analysis at the single-particle level in the solution.

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[2] Paul, S.S.; Lyons, A.; Kirchner, R.; *et al. ACS Nano* **2022**, 16(10), 16462.

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[4] Wu, D.; Xu, P.; Kelly, M. *Glycoconj. J.* **2023**, 40(4): 401.

[5] Young, G.; Hundt, N.; Cole, D.; *et al. Science*. **2018**, 360(6387), 423.

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Parallel session 19 - Biomedical & Well-Being Applications

2025-08-26
13:50 - 15:10
Parallel session 19 - Biomedical & Well-Being Applications

O19.1 - ENGINEERING CHITOSAN BIOHYDRID HYDROGELS FOR ADVANCED WOUND HEALING

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

Engineering Chitosan Biohydrid Hydrogels for Advanced Wound Healing

Qing, X.[a], Zanchetta, F.[b], Lima, M.H [b], Fardim, P.*[a]

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Chitosan is highly versatile polysaccharide for a multitude of advanced applications. Design and fabrication of biohybrids of chitosan with synthetic polymers or biopharmaceuticals is a very attractive approach to enhance the multifunctional properties of this material allowing the engineering of advanced systems for biomedical applications. In this work, the design and preparation of chitosan-based hybrid hydrogels with advanced properties will be presented and discussed. Polyvinyl alcohol (PVA)/N–succinyl chitosan (NSCS)/lincomycin hydrogels for wound dressing were prepared by the freezing/thawing method, then characterized by FTIR, SEM, and TGA. The compression strength, swelling behavior, water retention capacity, antibacterial activity, drug release and cytotoxicity were systematically investigated [1]. The results showed that the introduction of NSCS remarkably enhanced the swelling capacity, leading to the maximum swelling ratio of 19.68 g/g in deionized water. The optimal compression strength of 0.75 MPa was achieved with 30 % NSCS content. Additionally, the incorporation of lincomycin brought a remarkable antibacterial activity against both Escherichia coli and Staphylococcus aureus. Specifically, 77.71 % of Staphylococcus aureus was inhibited with 75 μg/mL lincomycin, while the MTT assay demonstrated the nontoxic nature of the composite hydrogels. In another approach [2], a hydrogel formulation containing insulin, chitosan, and hydroxypropyl methyl cellulose (Chi/HPMC/Ins) was prepared and characterized by FTIR, thermogravimetric, and gel point analyses. The in vitro cell viability and cell migration potential of the Chi/HPMC/Ins hydrogel were evaluated in human keratinocyte cells (HaCat) by MTT and wound scratch assay. The hydrogel was applied to excisional full-thickness wounds in diabetic mice for twenty days for in vivo studies. Cell viability studies indicated no cytotoxicity of the Chi/HPMC/Ins hydrogel. Moreover, the Chi/HPMC/Ins hydrogel promoted faster gap closure in the scratch assay. In vivo, the wounds treated with the Chi/HPMC/Ins hydrogel resulted in faster wound closure, formation of a more organized granulation tissue, and hair follicle regeneration. These results suggest that Chi/HPMC/Ins hydrogels might promote wound healing in vitro and in vivo and could be a new potential dressing for wound healing. In summary, the designed chitosan biohybrid hydrogels showed promising potential for wound dressing applications.

[1] Qing, X., He, G., Liu, Z., Yin, Y. Cai, W., Fan, L. & Fardim, P. Carbohydrate Polymers, 2021, 261, 117875, https://doi.org/10.1016/j.carbpol.2021.117875

[2] Zanchetta, F.C.; De Wever, P.; Morari, J.; Gaspar, R.C.; Prado, T.P.d.; De Maeseneer, T.; Cardinaels, R.; Araújo, E.P.; Lima, M.H.M.; Fardim, P. Bioengineering 2024, 11, 168. https://doi.org/10.3390/bioengineering11020168

O19.2 - Development of surface-modified nanocellulose scaffolds for tooth regeneration using dental pulp stem cells

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

Development of surface-modified nanocellulose scaffolds for tooth regeneration using dental pulp stem cells

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Dental regeneration research using human dental pulp stem cells (hDPSCs) has recently attracted attention with the aim of advancing difficult-to-regenerate tooth therapy. However, animal-derived materials are used as culture scaffolds for hDPSCs, resulting in immunogenicity, lot-to-lot variability and limited supply. In this study, we focused on cellulose nanofibers (CNFs), a plant-derived material, and hypothesized that the introduction of acidic functional groups on the crystalline CNF surface could mimic the fiber shape of collagen and disaccharide repeating structures such as hyaluronic acid in the *in vivo* environment of cells [1]. Here, TEMPO-oxidized CNF (TOCNF) and phosphorylated CNF (P-CNF) were used as novel modalities to prepare culture scaffolds, and immortalized hDPSC cell lines [2,3] were cultured to investigate cell proliferation and hard tissue differentiation behavior. After 72 hours of incubation, hDPSCs failed to adhere and formed spheroids on the unmodified CNF scaffold, whereas hDPSCs adhered and proliferated well on the surface-modified CNF scaffolds with appropriate amounts of functional groups, comparable to animal-derived collagen scaffolds (Figure 1). However, hDPSCs aggregated on the P-CNF scaffold with excessive amounts of phosphate groups, similar to the unmodified CNFs. Cell adhesion behavior dependent on the amount of acidic functional groups is a unique feature of CNF scaffolds that has been reported in other cell types [4]. We investigated the induction of hard tissue differentiation on the P-CNF scaffolds, and hDPSCs on appropriately modified P-CNFs showed increased gene expression and alkaline phosphatase activity, both of which are typical indicators of hard tissue differentiation, without the use of differentiation inducers. These findings suggest that P-CNFs with optimal phosphate content can directly promote the hard tissue differentiation of hDPSCs.

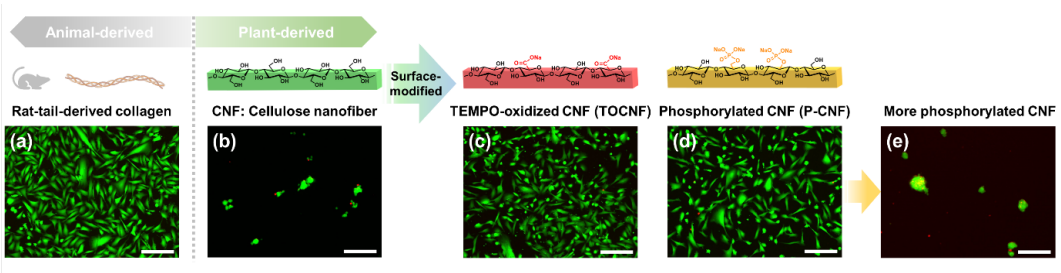

Figure 1. Live/dead cell images of immortalized hDPSCs after 72-h incubation on different scaffolds: (a) rat-

tail-derived type I collagen, (b) CNF, (c) TOCNF, (d, e) P-CNF (phosphate content: (d) 0.76, (e) 1.48 mmol/g). Live cells (green), dead cells (red). Scale bars: 200 μm.

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[2] Orimoto, A.; Kyakumoto, S.; Eitsuka, T.; Nakagawa, K.; Kiyono, T.; Fukuda, T., *Plos ONE* **2020**, *15*, e0229996

[3] Orimoto, A.; Addison, W. N.; Mochizuki, S.; Ariyoshi, W.; Ono, K.; Kitamura, C.; Kiyono, T.; Fukuda, T., *Cell Biochem. Funct.* **2024**, *42*, e4064

[4] Hatakeyama, M. & Kitaoka, T., *Cellulose* **2022**, *29*, 2869–2883

O19.3 - CHEMO-ENZYMATIC SYNTHESIS OF PEPTIDE BRIDGED GLYCAN NETWORKS

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

chemo-enzymatic synthesis of peptide Bridged glycan networks

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Bacterial peptidoglycans (PGs) are supramolecular networks of crosslinked, peptide-grafted glycan chains, which are crucial for mechanical stability and resistance of bacterial cell walls. Since PG-biosynthesis is an essential target for antibiotics, reproducing these structures is of high interest, as such pseudo-PG models could expand our understanding of bacterial cell walls. [1] Illuminating new pathways towards novel drug delivery systems or biomaterials for cell culture could also benefit from pseudo-PG models. However, many semi-synthetically produced pseudo-PG-constructs involve chemical methods that are tedious and wasteful. [2] Our work describes a new chemo-enzymatic approach for synthesis of pseudo-PGs using peptide-grafted alginate (**3**) and glycine-based linker molecules (red), which undergo protease-catalyzed crosslinking to yield viscoelastic gels with tunable mechanical properties. The enzymatic gelation processes were monitored via concentration, time- and temperature dependent oscillatory shear rheology and NMR experiments, yielding information about the kinetics of the peptide bridge formation and the viscoelasticity and stability of the pseudo-PGs. The gelation was further investigated in cell culture media to elucidate the strength and elasticity of the resulting pseudo-PG gels. We propose that this method has a high impact on biomaterials research, especially for peptide delivery, testing antibiotic efficacy or investigating human immune cell response.

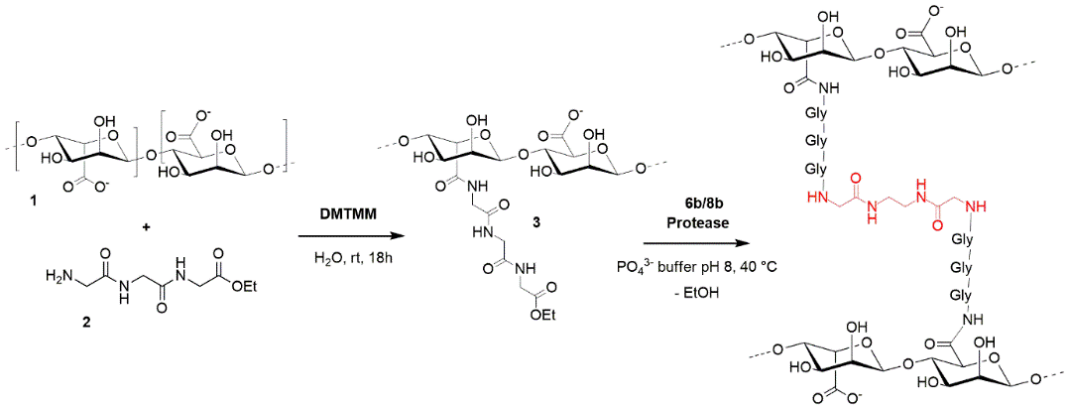

Figure 1. General synthetic strategy for pseudo-PGs.

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[2] C. M. Vacariu, M. E. Tanner, Recent Advances in the Synthesis and Biological Applications of Peptidoglycan Fragments. Chemistry – A European Journal 2022, 28, (43), e202200788.

O19.4 - HATU Coupling for Fast, Efficient, and Selective N-Acylation of Chitosan: DoE-Optimized Synthesis of N-(2-(N,N,N-Trimethylammoniumyl)acetyl)-chitosan.

Other
Biomedical & Well-being Applications

HATU Coupling for Fast, Efficient, and Selective N-Acylation of Chitosan: DoE-Optimized Synthesis of N-(2-(N,N,N-Trimethylammoniumyl)acetyl)-chitosan (TAC).

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Introduction: Chitosan is a natural, biodegradable, biocompatible, and non-toxic polysaccharide with significant antimicrobial activity, making it a promising candidate for drug delivery systems in treating bacterial infections. However, its practical applications are frequently limited by specific physicochemical constraints [1]. These challenges can be addressed through chemical modifications that enhance its properties. A notable chitosan derivative is *N*-(2-(*N,N,N*-Trimethylammoniumyl)acetyl)-chitosan (TAC), which shows improved solubility, increased membrane permeability, and strong antimicrobial effectiveness [2, 3].

Purpose: The previously reported synthesis of TAC involves the use of phthaloyl and triphenylmethyl [4], or tert-butyldimethylsilyl (TBDMS) protective groups [5] and *N*-acylation with *N*-chlorobetainyl chloride or bromacyl bromide (followed by reaction with trimethylamine), and deprotection. This method is resource-intensive and time-consuming. This study explores an alternative approach using a Design of Experiments (DoE) strategy to optimize the coupling of betaine to chitosan via Hexafluorophosphate Azabenzotriazole Tetramethyl Uronium (HATU) coupling, aiming for a high degree of substitution (DS) and efficiency.

Methods: Following preliminary investigations, two full factorial DoE optimizations of the reaction were performed, each involving 12 experiments, at 60°C using a Mya-4 reaction station with varying equivalent ratios of betaine, HATU, 1-hydroxybenzotriazole (HOBt), and triethylamine (TEA). The products were purified through ion exchange and dialysis, freeze-dried, and analyzed by ^{1}H-NMR (Figure 1).

Results and conclusions: The reaction optimization used MODDE software for data analysis to identify key parameters and optimal reagent conditions, achieving complete substitution efficiently and significantly reducing reaction time. The process enabled quantitative conjugation of betaine into the TAC derivative in three hours. Response surface modeling showed that HATU was the main factor influencing conversion.

The DoE approach identified crucial parameters and improved predictability of the final DS while reducing reagent use. This study created a novel, efficient method for TAC synthesis, enhancing sustainability and scalability and laying a foundation for future nanomedicine applications.

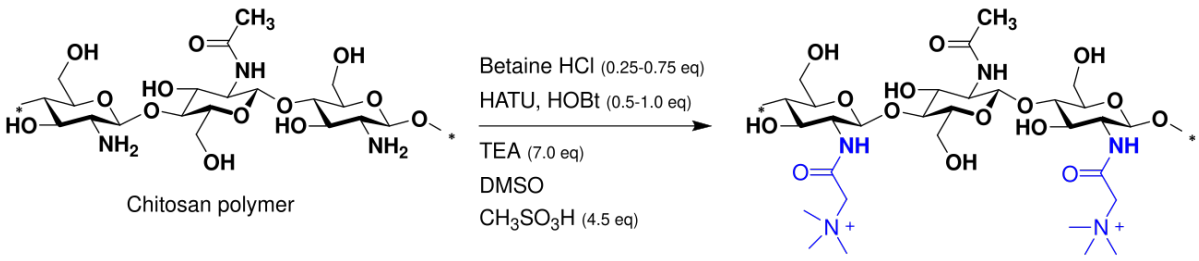

Figure 1: Reaction scheme for the HATU coupled procedure for TAC synthesis.

[1] M. Tian, H. Tan, H. Li, and C. You, "Molecular weight dependence of structure and properties of chitosan oligomers," *RSC Adv*, vol. 5, no. 85, pp. 69445–69452, 2015, doi: 10.1039/C5RA08358C.

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[3] J. Mannila, K. Järvinen, J. Holappa, L. Matilainen, S. Auriola, and P. Jarho, "Cyclodextrins and chitosan derivatives in sublingual delivery of low solubility peptides: A study using cyclosporin A, α-cyclodextrin and quaternary chitosan N-betainate," *Int J Pharm*, vol. 381, no. 1, pp. 19–24, Oct. 2009, doi: 10.1016/j.ijpharm.2009.07.012.

[4] J. Holappa *et al.*, "Synthesis and Characterization of Chitosan N-betainates Having Various Degrees of Substitution," *Macromolecules*, vol. 37, no. 8, pp. 2784–2789, Apr. 2004, doi: 10.1021/ma0358780.

[5] S. Rathinam, S. Ólafsdóttir, S. Jónsdóttir, M. Á. Hjálmarsdóttir, and M. Másson, "Selective synthesis of N,N,N-trimethylated chitosan derivatives at different degree of substitution and investigation of structure-activity relationship for activity against P. aeruginosa and MRSA," *Int J Biol Macromol*, vol. 160, pp. 548–557, Oct. 2020, doi: 10.1016/j.ijbiomac.2020.05.109.

Parallel session 20 - Materials & Engineering

2025-08-26
13:50 - 14:50
Parallel session 20 - Materials & Engineering

O20.1 - CHITOSAN-ITACONATE AS BINDER FOR HIGH-STRENGTH FIBREBOARDS

Textile, Pulp, Paper & Packaging
Materials & Engineering

Chitosan-itaconate as Binder for high-strength fibreboards

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Traditional engineered wood products, such as chipboards and fibreboards, effectively valorise wood scraps. However, their supply is increasingly challenged by competing applications like energy production. Additionally, conventional fibreboards rely on petrochemical-based binders, such as formaldehyde resins, which pose environmental and health concerns due to persistent emissions.

To address these issues, we have developed high-strength, water-resistant, and flame-retardant fibreboards using alternative plant-based materials, such as miscanthus, hemp shives, or Japanese knotweed, bound with a bio-based chitosan-itaconate binder. The chitosan-itaconate binder is designed to polymerise during hot pressing, effectively crosslinking the chitosan chains and ensuring superior mechanical properties [1]. Our results demonstrate that fibreboards bound with chitosan itaconate achieve bending strengths of up to 77 $N \cdot mm^{-2}$, outperforming conventional oriented strand boards (~25 $N \cdot mm^{-2}$) and even approaching the strength of solid spruce wood (~70 $N \cdot mm^{-2}$). Despite the crosslinked structure, biodegradability tests indicate good biodegradation rates similar to those of cellulose, further underscoring the ecological benefits.Compared to conventional fibreboards, our chitosan-itaconate bound boards offer a more sustainable and environmentally friendly alternative without compromising strength or workability. In addition, due to the inherent non-flammability of the binder, the boards do not burn even after prolonged exposure to flames [2]. This innovation represents a significant step towards greener and more resource-efficient construction practices, reducing waste while maintaining high performance standards.

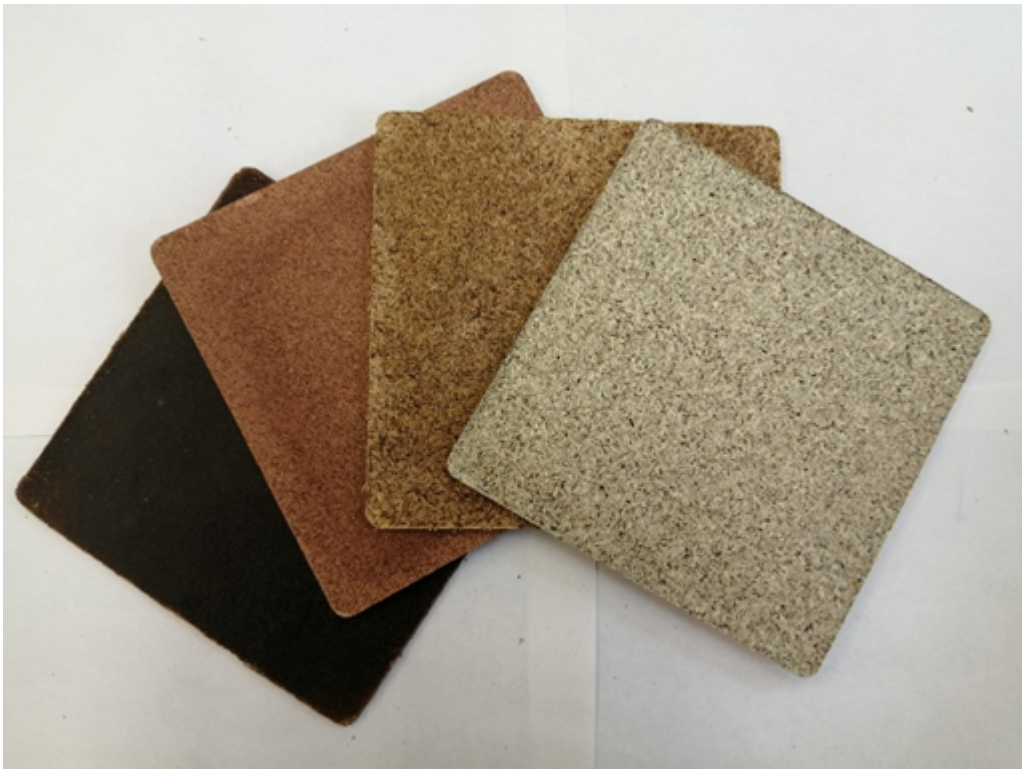

Figure 1. Chitosan-bound fibreboards (from left to right) produced with miscanthus at 150 °C and 10 wt% binder, produced at 125 °C and 10 wt% binder, produced at 125 °C and 5 wt% binder, and a hemp shives fibreboard with 5 wt% binder.

[1] Münstermann, N.; Weichold, O.; *Prog. Org. Coat.* **2024**, 194, 108630

[2] Münstermann, N.; Weichold, O.; *Prog. Org. Coat.* **2024**, 197, 108793

O20.2 - IMPROVED CELLULOSE FILMS BY PLASTICIZER BLENDING

Textile, Pulp, Paper & Packaging
Materials & Engineering

improved cellulose films by plasticizer blending

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Low-density polyethylene and polypropylene are commonly used for packaging for their lightweight, low cost and recyclability. In 2019, these materials accounted for 20% of the global plastic waste, which is projected to rise to over 1 billion tonnes by 2060 [1]. Only 17% of this waste is, however, anticipated to be recycled, while the rest would be incinerated, landfilled or mismanaged. European Commission recognized this challenge and suggested changes to packaging and packaging waste directive (94/62/EC), with the intention to promote waste prevention, reusability or recyclability of all packages by 2030 [2].

Transparent regenerated cellulose films are promising in various high-volume applications, such as for packaging. These films, however, lack elasticity and barrier against oxygen and water vapour. Vinyl-based polymers or aluminum oxide, are typically used to reduce permeability, but they difficult material recycling. Glycerol is commonly used to increase film elasticity, although it negatively impacts the film permeability. Studies on other bio-based plasticizers have mainly focused on oils and cellulose derivates, but the academia has thus far ignored the possibility of plasticizer blending. Thus, we studied the effects of glycerol, sorbitol, and maltitol blending using a systematic experimental design and determined regression models to correlate blend composition with film properties.

Our results showed that plasticizer blending enabled us to control film tensile strength and water vapour and oxygen permeabilities. Our films showed lower water vapor and oxygen permeabilities than commercial uncoated cellophane film, and could potentially provide a renewable alternative to conventional polyolefin films with further improvements. Our results are important to develop new plasticizer blending strategies to improve film performance [3]. Relationship between the plasticizers blends and their ability to describe actual film quality will be discussed.

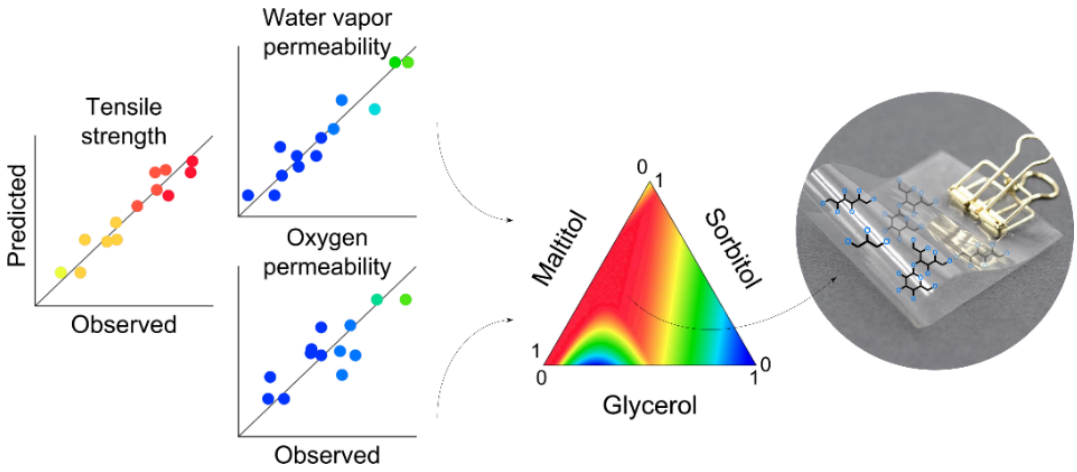


Figure 1. Schematic illustration of the model predictions combined to achieve targeted film properties.

[1] OECD, *Global Plastics Outlook: Plastic waste in 2019*, OECD Environment Statistics (database).

[2] Ragonnaud, G., *EU Legislation in Progress - Revision of the Packaging and Packaging Waste Directive*, Eur. Parliam. Res. Serv., **2023**, No. April.

[3] Ahokas, P.; Kunnari, V.; Majoinen, J.; Harlin, A., Mäkelä, M., *Plasticizer blending improved regenerated cellulose films as an alternative to plastics*, **2025**, Manuscript under review.

O20.3 - High-consistency quaternization of cellulose fibers and the effect on the fiber and fiber-network properties

Textile, Pulp, Paper & Packaging
Materials & Engineering

High-Consistency Quaternization of cellulose fibers and the effect on the fiber and fiber-network properties

Sjölund, J.*[a], Westman, G.[b], Wågberg, L. [a], Larsson, P. A.[a]

[a] FibRe Centre for Lignocellulose-based Thermoplastics, Department of Fibre and Polymer Technology, KTH Royal Institute of Technology, SE-10044 Stockholm, Sweden

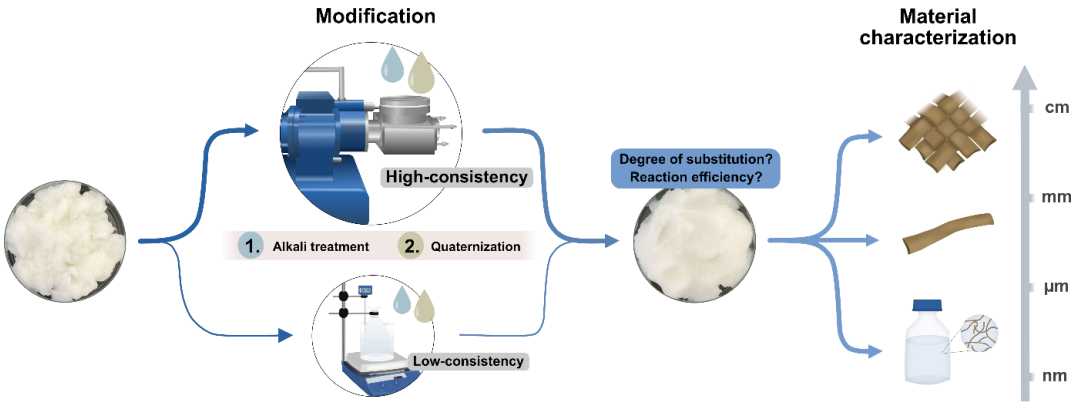
[b] FibRe Centre for Lignocellulose-based Thermoplastics, Department of Chemistry and Chemical Engineering, Chalmers University of Technology, SE-41296 Gothenburg, Sweden

Presenting author: Johanna Sjölund, johsjol@kth.se

Quaternized cellulose fibers and cellulose nanofibrils (CNFs) are attractive candidates for the development of new renewable and biodegradable materials. However, the etherification reaction, through which the functionalization is commonly achieved, provides low efficiencies, limiting industrial interest in the modification. This work primarily aims to increase the efficiency for the quaternization of cellulosic fibers while keeping the fiber structure intact. This was achieved using high-consistency kneading to mix and modify the fibers at far higher solids contents than previously reported, efficiently limiting the alkaline hydrolysis of the reagent. By subjecting the fibers to a semi–dry kneading quaternization process, a tenfold improvement of the reaction efficiency, and efficiencies up to 40%, could be reached compared to the values usually presented in the literature.

The fibers obtained after the high-consistency quaternization process are naturally affected by the chemical modification and the mechanical treatment that they have been subjected to. For example, an increased fibrillation and swelling of the fibers could be visualized with light microscope and further analyzed by fiber dimension analysis, fiber saturation point measurements and fines determination. This also affect the properties of the sheets produced from the fibers. While quaternization alone mainly enhances the strainability of the material, the simultaneous mechanical treatment of the fibers also enhances the stress-at-break of the material, providing a though material. The presence of quaternized groups also makes the fibers susceptible to take up, and be softened, by moisture, providing a viable path to further increase the strainability and achieve a 3D-formable material.

Altogether, this work demonstrates a scalable, high-reaction-efficiency approach for quaternization of cellulose fibers which yields promising physical properties of the fibers and materials made therefrom and, lastly, some inspiration to what these materials can be used for.



[1] Sjölund, J., Westman, G., Wågberg, L., & Larsson, P. A. (2025). *High-consistency modification of cellulose fibers: Resource-efficient introduction of cationic charges, and their effect on fiber and nanofibril properties.* Carbohydrate Polymers, 123254.

Parallel session 21 - Chemistry, Biology & Physics

2025-08-27
11:30 - 12:30
Parallel session 21 - Chemistry, Biology & Physics

O21.1 - Sterically stabilized cellulose nanocrystals by Jeffamine grafting: preparation, characterization and colloidal stability

Polysaccharide Colloids
Chemistry, Biology & Physics

Sterically stabilized cellulose nanocrystals by Jeffamine grafting: preparation, characterization and colloidal stability

Grachev, V.[a,b], Koso, T.[c], De Frene, T.[b], King, A.W.T.[c], Bartic, C.[d], Thielemans, W.[b], Szilágyi, I[a].

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[b]Sustainable Materials Lab, KU Leuven KULAK, Etienne Sabbelaan 53, B-8500 Kortrijk

[c]Biomass Processing and Products, VTT Technical Research of Finland Ltd, FI-02044 Espoo

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Sterically stabilized cellulose nanocrystals (CNCs) were obtained by hydrolysis of cotton wool with hydrochloric acid, by subsequent TEMPO-mediated oxidation, and by amidation of the resulting carboxylated CNCs with amine-terminated amphiphilic polymer Jeffamine ED-2003 mediated by 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide and N-hydroxysuccinimide. The covalent attachment of Jeffamine onto the CNCs was confirmed by infrared spectroscopy, solution-state nuclear magnetic resonance spectroscopy[1], and elemental analysis. It was shown that the amide graft forms in a competition with the N-acylurea by-product of amidation. Jeffamine grafting resulted in a change in thermal behavior of CNCs, resulting in a two-step thermal degradation and melting behavior similar to the pure Jeffamine. The obtained Jeffamine-grafted CNCs were found to form stable colloidal aqueous suspensions over a broad range of concentrations of sodium chloride, in the presence of various other cations and anions, as well as in physiologically relevant solutions, making them interesting to be used in the media with high ionic strength[2].

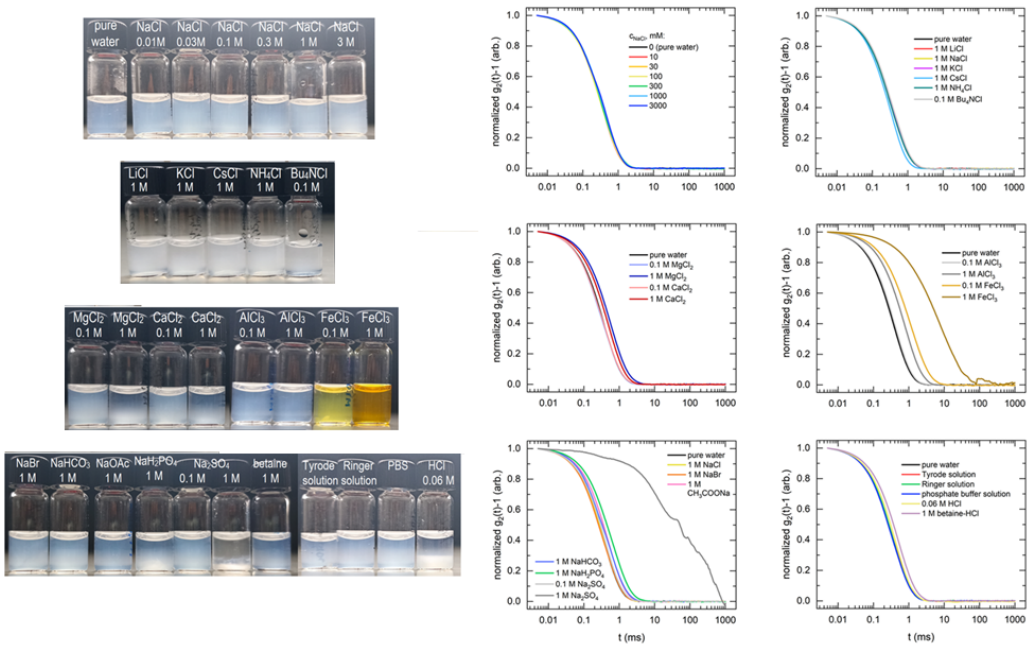

Figure 1. Photographs of 1% Jeffamine-grafted CNC suspensions in the presence of various salts (left) and dynamic light scattering data of 0.1% grafted CNC suspensions (right)

[1] King, A.W.T. et al. *Biomacromolecules* **2018**, *19*, 2708-2720.

[2] Azzam, F. et al. *Biomacromolecules* **2016**, *17*, *6*, 2112-2119.

O21.2 - 13C solid-state NMR of polysaccharide assemblies: a new approach showing the involvement of water in the organization of macromolecules

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

^{13}C solid-state NMR of polysaccharide assemblies: a new approach showing the involvement of water in the organization of macromolecules

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Structural and dynamic information on polysaccharide assemblies at the nanometric scale can be assessed by solid-state ^{13}C NMR spectroscopy. Amongst the various NMR sequences, the VCT-CPMAS (Variable Contact Time-Cross Polarization Magic Angle Spinning) provides parameters ($T_{1\rho}^{H}$ spin lattice relaxation time in the rotating frame, T_{HH} spin diffusion time) that characterize the mobility of macromolecules in hydrated assemblies including a particular water structuring through hydrogen bonds.

The VCT-CPMAS is generally underused due to time constraints. Moreover, extraction of the dynamical parameters from the experimental data relies on several complex mathematical models. An optimized VCT-CPMAS experimental and processing pipeline was developed [1], making possible the determination of different dynamics, of which spin diffusion times that offer novel insights into water dynamics within the polysaccharide matrices, and $T_{1\rho}^{H}$ that reflects the overall level of organization resulting from interactions (Figure 1). This approach was implemented on samples of increasing complexity including different celluloses [2] and starches of different botanical origins whose water content has been modulated. Applied to binary films of cellulose and hemicellulose, this approach demonstrated the ability of T_{HH} to predict water retention capacity of the complex assemblies [3]. The initial results from real complex matrices (e.g., wood, vegetable, and fleshy fruit cell walls) demonstrate that spectral resolution is enough to distinguish between the dynamics of the various macromolecular components (cellulose, pectins, lignins, cutins). Thus, ^{13}C VCT-CPMAS NMR spectroscopy makes easier the dynamical and structural characteristics investigations of different polymers, in relation with their functional role in complex hydrated matrices.

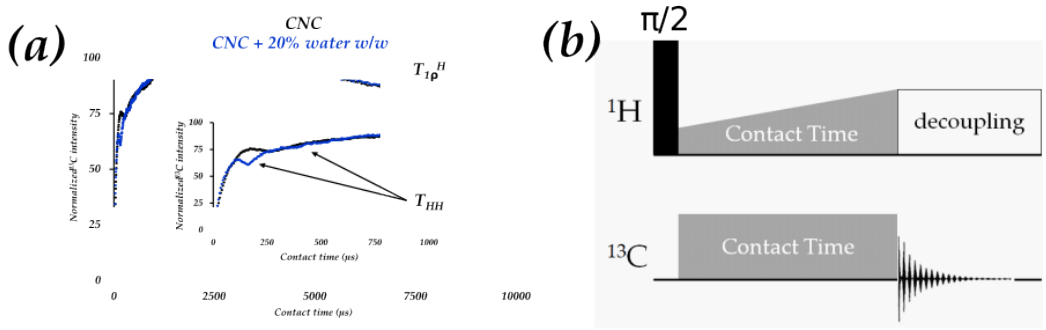

Figure 1: (a) Evolution of the ^{13}C signal intensity as a function of the contact time in (b)VCT-CPMAS sequence (magnetization transfer from ^{1}H to ^{13}C). The increasing and decreasing parts of the signal are assigned to spin diffusion times T_{HH} and relaxation time in the rotating frame $T_{1\rho}^{H}$, respectively.

[1] Falourd, X., Lahaye, M., & Rondeau-Mouro, C., MethodsX, **2022**, 101914, 9.

[2] Falourd, X., Lahaye, M., & Rondeau-Mouro, C., Carbohydrate Polymers, **2022**, 120104, 298.

[3] Falourd, X., Rondeau-Mouro, C., Cambert, M., Lahaye, M., Chabbert, B., & Aguié-Béghin, V., Carbohydrate Polymers, **2024**, 121579, 326.

O21.3 - MODIFICATION OF DIALDEHYDE CELLULOSE FOR IMPROVED RHEOLOGICAL AND WATER ABSORPTION PROPERTIES OF HYBRID SUPERABSORBENT

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

MODIFICATION OF DIALDEHYDE CELLULOSE FOR IMPROVED RHEOLOGICAL AND WATER ABSORPTION PROPERTIES OF HYBRID SUPERABSORBENT

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This study investigates the valorization of banana tree fibers through cellulose extraction. Cellulosic fibers were used as biobased materials for synthetizing superabsorbent polymers (SAPs) with high water absorption capacity. Cellulose was oxidized using sodium periodate to produce dialdehyde cellulose (DAC), which was further modified via a Horner-Wadsworth-Emmons (HWE) reaction to yield dialdehyde cellulose acrylate (DACAcr) (figure 1a). This modified cellulose acted as both a copolymer and a grafting agent in hybrid SAP synthesis (DACAcr-g-poly(AA-IA)) using acrylic acid (AA), itaconic acid (IA), and N,N′-methylenebisacrylamide (MBA) as a cross-linker (figure 1b). The introduction of sodium propenoate units enhanced copolymerization and increased hydrophilic carboxylate group density.

The synthesized SAPs were characterized using FTIR, SEM, and rheological analysis. Kinetic studies revealed outstanding water absorption capacity, with SAP- DACAcr-g-poly(AA-IA) achieving up to 1441 ± 59 $g \cdot g^{-1}$ in distilled water and 120 ± 10 $g \cdot g^{-1}$ in in a 0.9 wt% NaCl saline solution. These results highlight the potential of DACAcr-based materials as eco-friendly, high-performance alternatives to conventional SAPs for water management, leveraging agricultural waste for sustainable solutions.

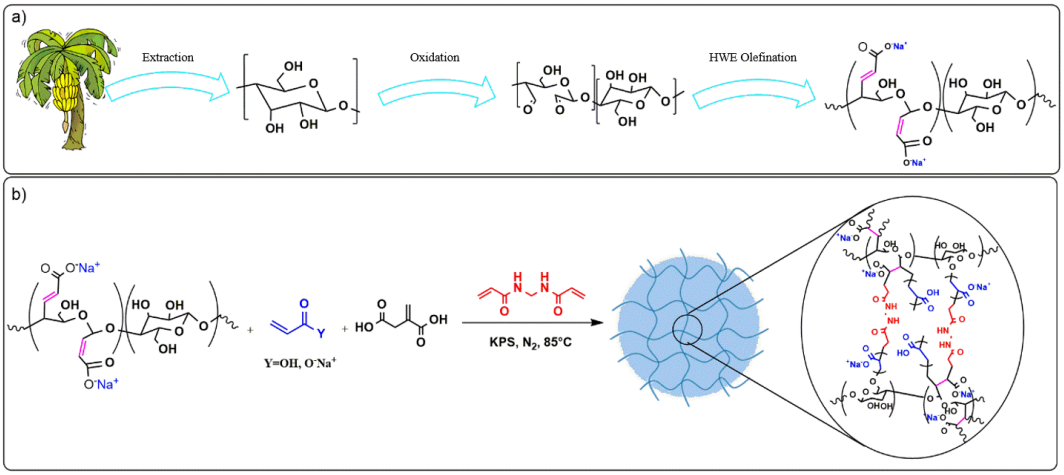

Figure 1. Synthesis Scheme of (a) DACAcr and (b) DACAcr-g-poly(AA-IA).

Parallel session 22 - Chemistry, Biology & Physics

2025-08-27
11:30 - 12:10
Parallel session 22 - Chemistry, Biology & Physics

O22.1 - CHARACTERIZATION OF PLANT CELLULASES FOR DEPOLYMERIZATION OF CELLULOSE AND HEMICELLULOSE

Other
Chemistry, Biology & Physics

Characterization of Plant cellulases for depolymerization of cellulose and hemicellulose

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Cellulose is a major renewable resource for a wide variety of sustainable industrial products. However, for its utilization, finding new efficient enzymes for plant cell wall depolymerization is crucial. In addition to microbial sources, cellulases also exist in plants, however, they have been less studied so far. All plant cellulases belong to glycoside hydrolase family 9 (GH9) of endo-1,4-β-glucanases (EGases; EC 3.2.1.4) divided into three subgroups. Whereas GH9A-type cellulases are associated with cellulose synthesis, GH9B- and GH9C-type cellulases are associated with cellulose depolymerization. Many processes in plants include enzymatic cell wall hydrolysis and EGase activity has been detected during organ abscission, fruit ripening/softening and plant-to-plant parasitic interactions [1,2].

In vitro activity tests, using recombinant proteins of plant GH9 cellulases produced in yeast have indicated a wide range of carbohydrate substrates for plant GH9 cellulases, including crystalline and soluble celluloses as well as various hemicelluloses. Thus, plant GH9 cellulases have overlapping activities with other plant carbohydrate-active enzymes (CAZymes), such as GH5-7, GH10, GH16 and GH17. We have studied the GH9 gene family in parasitic dodder *Cuscuta campestris* which is a common and problematic parasitic plant relying on haustoria to connect to and siphon nutrients from host plants. Our studies have revealed 22 GH9 family members in the dodder genome, which encode fifteen secreted and seven membrane-anchored cellulases. The genes encoding secreted B- and C-type GH9 cellulases are suggested to play critical roles in degradation of host cell walls during host invasion [2]. Functional analyses of the recombinant *Cuscuta* B- and C-type cellulases showed high EGase activities over wide pH and temperature conditions, and activities towards multiple cellulose and hemicellulose substrates. These findings improve our understanding of host cell wall disassembly by *Cuscuta,* and cellulase activity towards a broad substrate range potentially explain its wide host range. Based on our study, *Cuscuta* cellulases may have potential applications in industrial bioprocessing and have been subjected to further investigation and optimization of their performance.

Figure 1. Parasitic dodder (*Cuscuta campestris*).

[1] Edema, H.; Ashraf, M.F.; Samkumar, A.; Jaakola, L.; Karppinen, K, *Carbohydr. Polym.* **2024**, *343*, 122493

[2] Edema, H.; Bawin, T.; Olsen, S.; Krause, K.; Karppinen, K, *Plant Physiol. Biochem.* **2024**, *210*, 108633

O22.2 - Enzymatic Coupling of Ferulic Acid to Pullulan: Structural Analysis, Physicochemical Properties, and Antioxidant Activity

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Enzymatic Coupling of Ferulic Acid to Pullulan: Structural Analysis, Physicochemical Properties, and Antioxidant Activity

BOUNDAOUI K., LE CERF D., **DULONG V*.**

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A sustainable approach via the use of enzymes was chosen to functionalize a polysaccharide with phenolic compounds. Using biocatalysis instead of conventional chemical reactions allows many of the principles of green chemistry to be respected, such as pollution prevention, less hazardous chemical syntheses, and safer solvents and auxiliaries, to name a few. To conduct this study, laccase from *Myceliophthora thermophila* has been chosen as oxidoreductase enzyme, pullulan (Pull) as neutral polysaccharide and ferulic acid (FA) as phenolic compound. Until now, laccases were mainly used to catalyze the functionalization reactions of chitosan with phenolic compounds and the mechanisms are described as a two-step reaction: in the first step, the laccase oxidizes the phenolic compounds into quinones and in the second step, the oxidized products react with chitosan via the Schiff base reaction or by Michaël addition [1]. In our case, Pull only bears hydroxyl groups like dextran whose enzymatic functionalization has been described in a few articles with curcumin, catechin or phenoxodiol but the coupling mechanism is not proposed and remains unclear [2].

In our study, we aimed to elucidate the mechanism of coupling reaction of FA to Pull via laccase catalysis and proposed a potential structure for FA dimers grafted onto Pull. The hydrophobic and ionic character of FA dimers imparted an amphiphilic behavior to Pull-FA with intra- or interchain interactions depending on concentration and pH. Pull-FA derivatives also exhibited antioxidant properties.

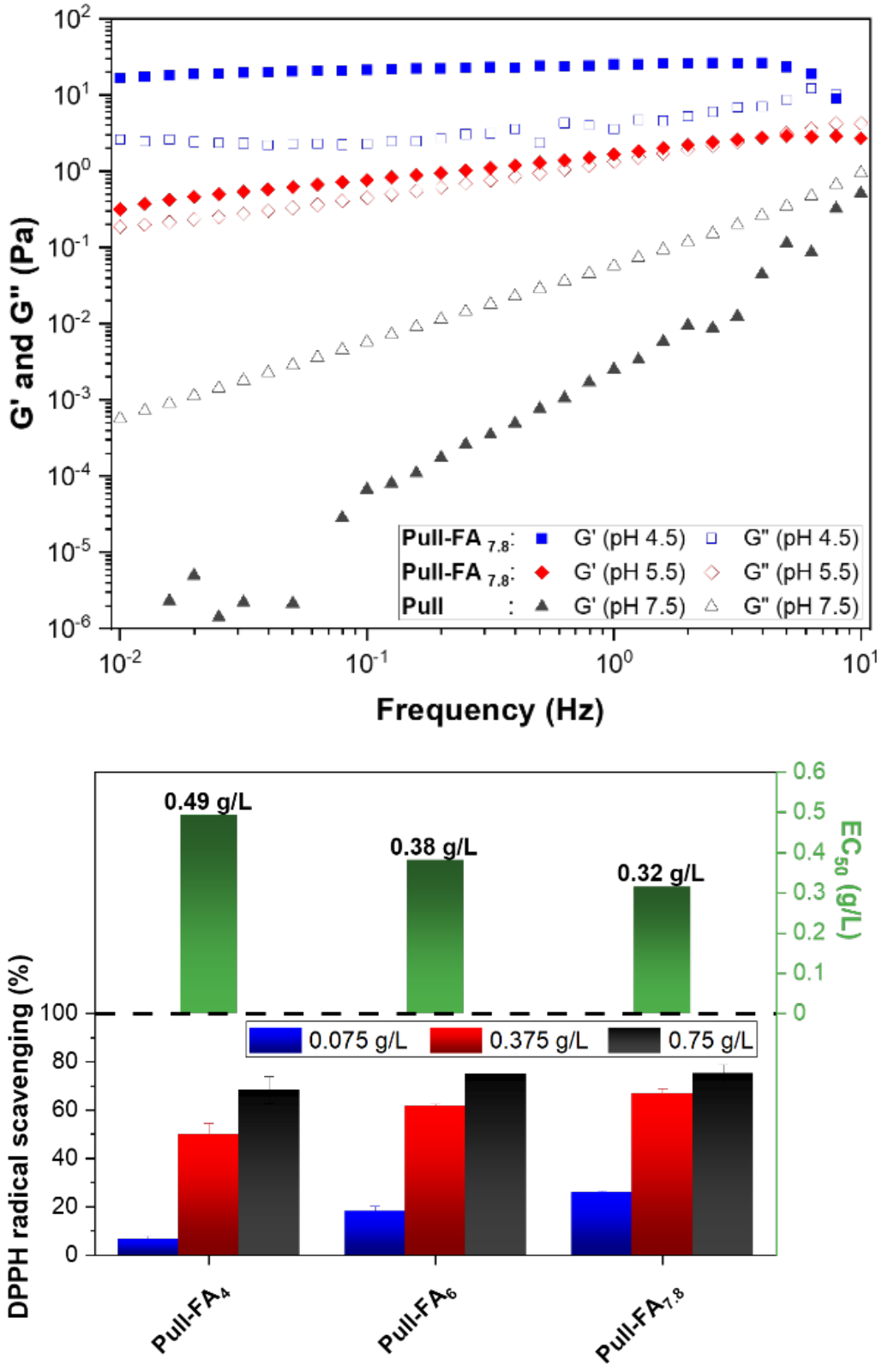

Figure 1: Rheological study of the hydrogels (left) antioxidant properties of the hydrogels (right)

[1] Božič M, Štrancar J, Kokol V (2013), React Funct Polym 73:1377–1383

[2] Boundaoui K, Le Cerf D, Dulong V (2024) Int J Biol Macromol 283, 137660

Parallel session 23 - Materials & Engineering

2025-08-27
11:30 - 12:10
Parallel session 23 - Materials & Engineering

O23.1 - 3D printing of bio-inspired hydrogel for photosynthetic cell immobilization and production of chemicals

3D Printing and Additive Manufacturing
Materials & Engineering

3D printing of bio-inspired hydrogel for photosynthetic Cell immobilization and production of chemicals

Tim Salomäki*[a], Elia Marelli[b], Gabor Toth[b], Ellen Sundström[a], Valter Georgs[a], Oskar Backman[a], Hao Zhang[a], Yagut Allahverdiyeva[b], Chunlin Xu[a]

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Polysaccharides such as cellulose and hemicellulose are increasingly recognized as versatile building blocks for sustainable materials engineering, particularly in the context of 3D printing. Hemicellulose and cellulose possess intrinsically high affinity providing strong mechanical strength to plant cell walls and thus inspiring design of strong hydrogel. Their abundance in nature, biodegradability, and tuneable properties make them the perfect candidates for the bioinks used in the creation of engineered living materials or photosynthetic cell factories (PCF) [Rissanen et al. 2021]. However, one of the challenges in PCF systems, which use microorganisms like cyanobacteria to produce valuable chemicals, is inefficient light utilization due to self-shading, which limits the productivity of the system. 3D printing with bioink has emerged as a promising solution to overcome these challenges by enabling precise control over cell placement and scaffold architecture (Toth et al. 2023).

In our research, 3D-printed bio-scaffold composed of TEMPO-oxidized cellulose nanofibrils (TCNF) and methacrylated galactoglucomannan (GGMMA) hydrogel is designed to immobilize ethylene-producing cyanobacteria as solid-state PCF. This nanocellulose-based scaffold provides a highly transparent and porous matrix, intended to support better light distribution and reduce self-shading. The TEMPO-oxidized fibers improve light transmission and contributes to the mechanical reinforcement of the scaffolds. Meanwhile GGMMA forms a photocrosslinkable network, enabling rapid curing under UV light to yield tuneable rigidity and durable structural stability. Rheological measurements and mechanical testing demonstrate that by adjusting GGMMA content from 0.5% to 2%, the rigidity of the printed structure increased by a factor of ten, significantly improving mechanical stability for applications without degrading the ethylene production of the films. The printed hydrogels also support long-term cell viability without deformation, highlighting the natural compatibility of these biomaterials with living cells. The optimized ink composition shows excellent printability, enabling future complex 3D architectures (e.g., multi-layer lattices) that can be tailored for optimal light distribution and nutrient flow. Collectively, these material features highlight the potential of polysaccharide bioinks for fabricating next generation engineered living materials with

improved light utilization for photosynthetic processes, mechanical resilience, and scalability.

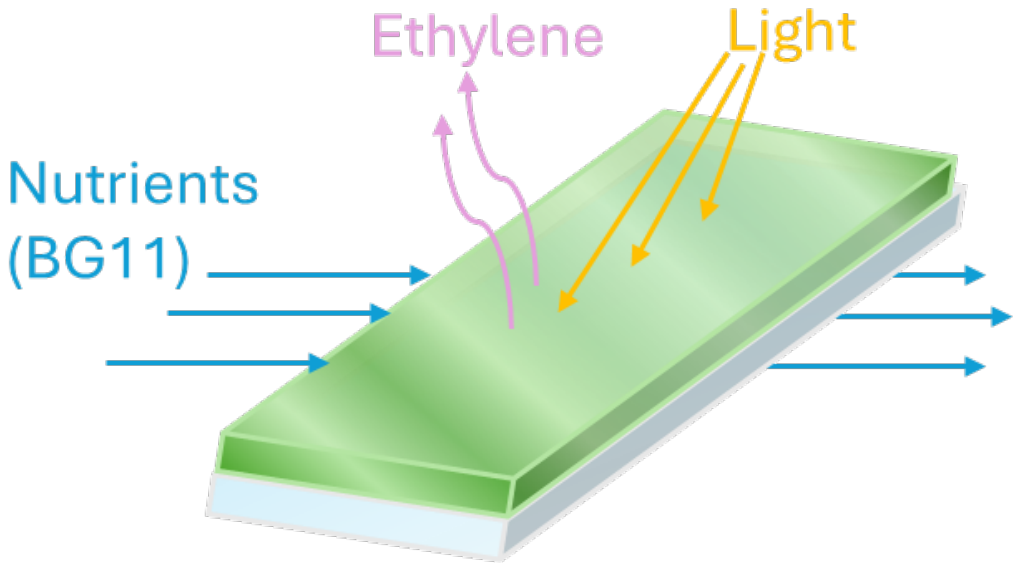

Figure 1. Design for thin-film photosynthetic cell factory

[1] Rissanen et al 2021 DOI: 10.1039/d1gc00502b

O23.2 - 3D PRINTING PLANT CELL WALL MATERIAL BASED COMPOSITE: THE EVALUATION OF INK PRINTABILITY & STABILITY COMPOSED OF PECTIN, HEMICELLULOSE AND CELLULOSE

3D Printing and Additive Manufacturing
Materials & Engineering

3D PRINTING OF PLANT CELL WALL MATERIAL BASED COMPOSITE: THE EVALUATION OF INK PRINTABILITY & sTABILITY COmposed of pectin, hemicellulose and cellulose

Bandyopadhyay, S.*[a], Puzhakkara, V. A.[a], Chibrikov, V.[a], Cybulska, J.[a], Zdunek, A.[a]

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Pectin, hemicellulose and cellulose are assembled in plant cell wall to perform mainly the mechanical function to the plant. Therefore, they are perfect candidates to develop new biomaterials with tunable mechanical properties. Adaptability, lack of immune response, shear-thinning properties, ease of printing, compatibility with biological systems, and ability to degrade naturally makes these polysaccharides a promising 3D printing ink component.

Thus, the aim of this experiment was to use develop the ink made of all three polysaccharides for 3D printing. Different compositions of the ink composed of low-methylated pectin (LM), xyloglucan (XG) and cellulose nano-crystals (CNC) at different concentrations have been evaluated. The compositions were prepared in an aqueous medium at stirring speed of 30000 rpm. The viscoelastic behavior of the ink was evaluated under parallel plate geometry at two shear rates (1 s^{-1} and 100 s^{-1}) and shear rate ramp with steady sensing from 0.1 – 100/s. Uniformity in the printing structure and overview of the internal structures of the printed materials were also analyzed using optical and scanning electron microscope (SEM), respectively. Mechanical properties of the printed objects in compression and tensile tests were studied as well.

Obtained results have shown that the viscosity of the polysaccharide mix increases with an increase in their concentration in the inks. Selected composites have evidential shear thinning properties, which is important for extrusion-based 3D printing. The values of the yield stress allow prediction stability of the post printed structure. SEM images have confirmed the presence of porosity in the printed layered structures, which may also contribute to the parameters related to structural stability. The mechanical evaluation found differences in mechanical properties among the samples.

Acknowledgement

Current study was supported by the National Science Centre, Poland as a part of OPUS25 project (grant nr – 2023/49/B/NZ9/02979).

Parallel session 24 - Materials & Engineering

2025-08-27
11:30 - 12:30
Parallel session 24 - Materials & Engineering

O24.1 - POLYSACCHARIDES IN WASTEWATER TREATMENT: PROMISING GREEN FLOCCULATION AGENTS

Sustainable Materials/Circular Economy
Materials & Engineering

Polysaccharides in wastewater treatment:
Promising green flocculation agents

Leonhartsberger Simon*[a], Carmona, P.[a], Mann, K.J.[b], Kozich, M.[b], Stanetty, C.[a], Mihovilovic, M.D.[a]

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With a growing global population, developing effective and more sustainable strategies for removing impurities from water is becoming an increasingly critical task.

In this context, wastewater treatment plants and their associated processes play a vital role in enhancing the efficiency of water purification. One commonly employed approach is coagulation-flocculation, which facilitates the aggregation of fine particles, thereby enabling their removal through sedimentation, filtration or centrifugation. However, the additives typically used for this purpose, such as cationic polyacrylamides (cPAM), are known to pose environmental and health risks, thus more sustainable and eco-friendly alternatives are urgently required [1].

In a recent study, we filled a gap in the systematic investigation of polysaccharides as flocculation agents, and highlighted the potential of modified polysaccharides in wastewater treatment which represent environmentally friendly and biodegradable alternatives to conventional synthetic materials. Key parameters such as molecular weight and charge density significantly influence the effectiveness of these biopolymers [2]. More recently, we studied the type of chemical modification and their combinations, which can have a strong impact on the performance of the materials, as demonstrated in some examples in Figure 1. In certain cases, we observed that modified polysaccharides can match the efficiency of synthetic counterparts while exhibiting significantly greater biodegradability.

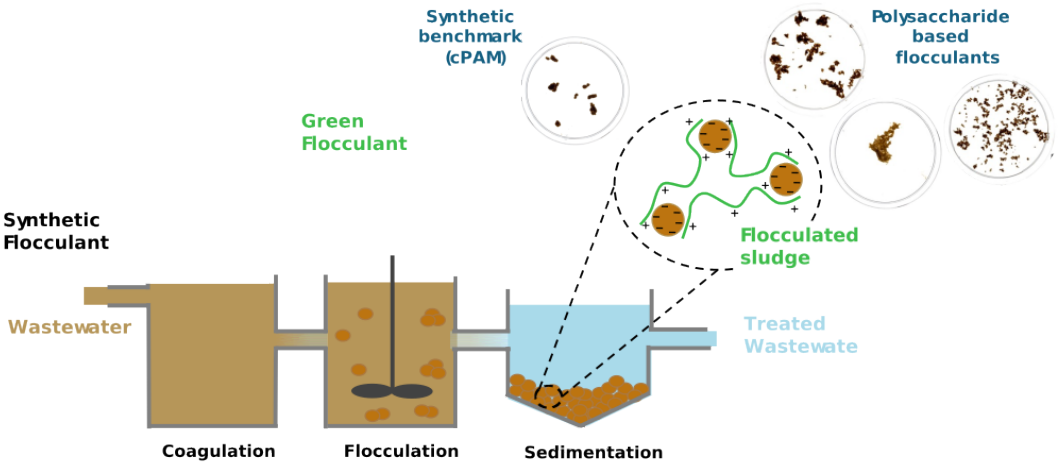

Figure 1. Modified polysaccharides in wasterwater treatment – possible alternatives to synthetic benchmark materials for coagulation-flocculation

[1] Fan, M., Xu, X., Lang, W., Wang, W., Wang, X., Xin, A., ... & Zhu, B. (2023). Toxicity, formation, contamination, determination and mitigation of acrylamide in thermally processed plant-based foods and herbal medicines: A review. Ecotoxicology and Environmental Safety, 260, 115059.

[2] Leonhartsberger, S.; Carmona, P.; Seidl, B.; Mann, K.-J.; Kozich, M.; Sulaeva, I.; Stanetty, C.; Mihovilovic, M. D., Polysaccharides-based green flocculants: A systematic and comparative study of their coagulation-flocculation efficiency. *Carbohydrate Polymers* **2025**, 123527.

O24.2 - INNOVATIVE CELLULOSE-BASED SUSTAINABLE FLOCCULANTS FOR ENHANCED WASTEWATER TREATMENT

Sustainable Materials/Circular Economy
Materials & Engineering

Innovative Cellulose-Based Sustainable Flocculants for Enhanced Wastewater Treatment

Magalhães, S.[*a], Alves, L.[b], Medronho B.[a,c], Rasteiro M.D.G.[b], Svanedal I.[a] and Norgren M.[a]

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Many studies highlight the potential of cellulose as a sustainable alternative to widely used synthetic polymers in industry [1]. As a polymeric material, cellulose exhibits several desirable properties. However, its poor solubility in common solvents and lack of thermoplasticity pose significant challenges. To overcome these limitations, strategic chemical modifications are essential to enhance cellulose's reactivity and expand its applications.

In our research, we employed controlled cationic and hydrophobic modifications to produce cellulose derivatives with different degrees of substitution, molecular weight, and hydrophobicity. These modifications were designed to improve cellulose's performance as a flocculant for removing emergent contaminants, such as textile fibres, from wastewater treatment plants [2]. The cationization process involved a two-step approach: initial oxidation with periodate followed by reaction with a cationic agent (Girard T reagent). Simultaneously, hydrophobic modification was achieved following green chemistry principles by using renewable feedstocks derived from plant oils. Fatty acids were extracted from vegetable oils, and cellulose was esterified in methanol.

The ecotoxicity of cationic and hydrophobic cellulose derivatives, each with three trophic levels using algae (R. subcapitata), water fleas (D. magna), and zebrafish embryos (D. rerio). Additionally, flocculation efficiency was assessed in contaminated effluents using laser diffraction spectroscopy, optical microscopy, and scanning electron microscopy. The bioflocculants developed in this study successfully aggregated and removed model microplastics (PE and PET) from aqueous media.

Overall, this work demonstrates that bio-based flocculants offer promising and tunable solutions for textile fibers removal, reducing their potential environmental impact [3]. Furthermore, the bioflocculants showed significantly lower toxicity compared to commercial polyacrylamides commonly used in wastewater treatment plants.

References

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[2] S. Magalhães, M.J. Aliaño-González, P.F. Cruz, R. Rosenberg, D. Haffke, M. Norgren, L. Alves, B. Medronho, M. da Graça Rasteiro, Customising Sustainable Bio-Based Polyelectrolytes: Introduction of Charged and Hydrophobic Groups in Cellulose, Polymers, 16 (2024) 3105, https://doi.org/10.3390/polym16223105.

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O24.3 - CELLULOSE NANOCRYSTALS FOR SUSTAINABLE FLOTATION SEPARATION OF CYANOBACTERIA MICROCYSTIS AERUGINOSA

Sustainable Materials/Circular Economy
Materials & Engineering

Cellulose nanocrystals for sustainable flotation separation of cyanobacteria *Microcystis aeruginosa*

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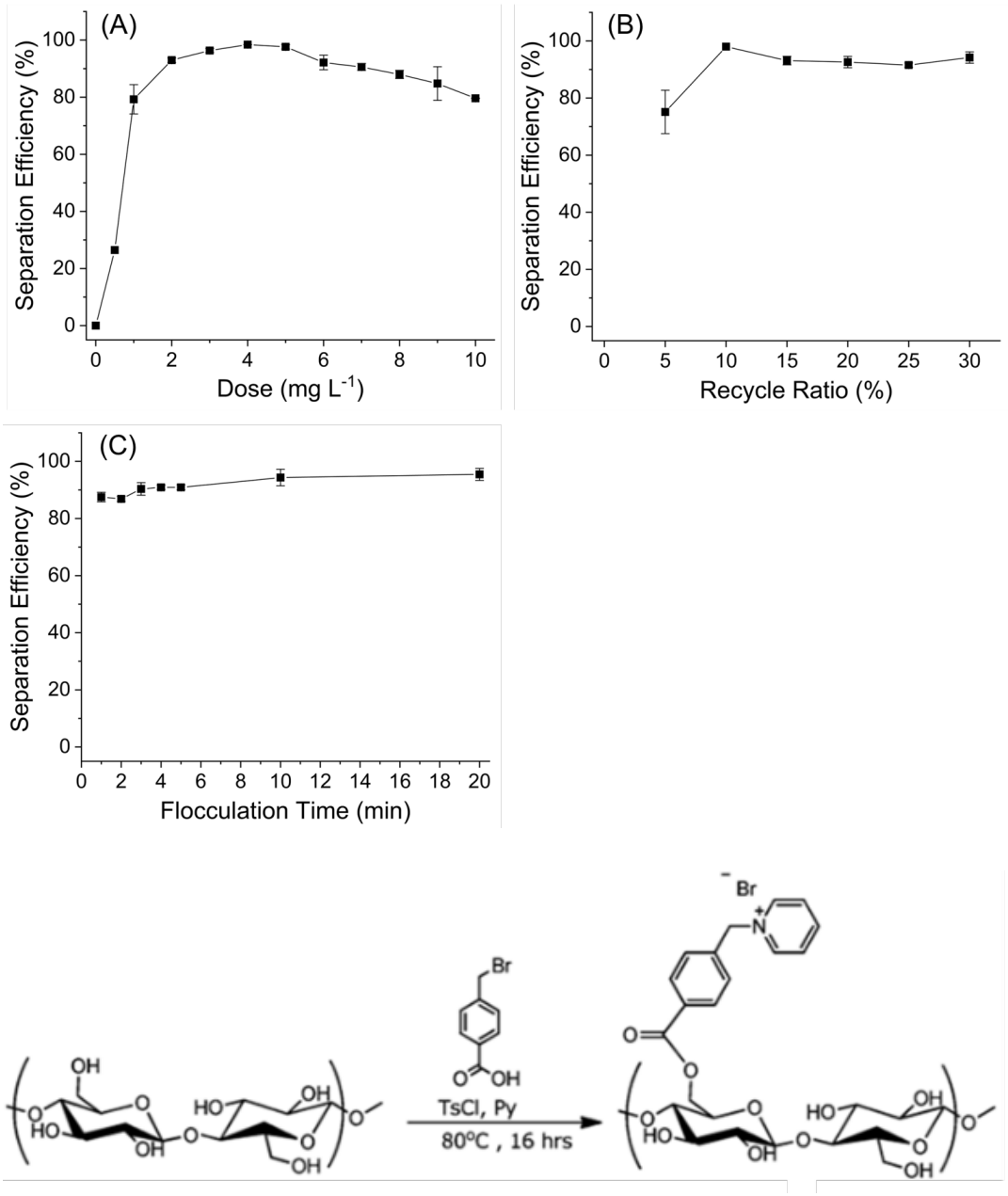
Flocculants are extensively utilized in water treatment to aggregate cyanobacterial cells into larger flocs, facilitating their removal via dissolved air flotation (DAF). Recently, polysaccharides have attracted significant attention as non-toxic and sustainable alternatives to conventional flocculants[1]. This study investigated the use of naturally derived cellulose nanocrystals (CNCs), extracted from cotton and chemically modified with cationic pyridinium grafts (CNC-PYR), to separate the harmful cyanobacteria *Microcystis aeruginosa* from water. The degree of grafting on the CNCs was characterized using elemental analysis, FTIR, and XPS, while their crystallinity was assessed via WAXS.

The flocculation efficiency of CNC-PYR improved with increasing doses, achieving > 95 % separation with only 2 mg L^{-1} dose. Notably, the performance of CNC-PYR was comparable to that of the synthetic polymer poly(diallyldimethylammonium chloride) (PDADMAC), widely used in water treatment plants globally.

Monitoring the fate of flocculants is crucial for improving water treatment processes. A key advantage of CNC-PYR flocculants lies in the fluorescent properties of the pyridinium groups, enabling the tracking of residual flocculants in treated water—an advantage not offered by non-traceable PDADMAC. Furthermore, acute toxicity assays (48-hour exposure) using *Daphnia magna* and *Chlorella vulgaris* revealed negligible toxicity for CNC-PYR, in stark contrast to the highly toxic PDADMAC residual monomers in the effluent post-flocculaiton.

These findings highlight the potential of modified polysaccharide-based flocculants such as CNC-PYR to advance sustainable water treatment practices. Their high efficiency, trackability, and low environmental impact make them promising candidates for widespread adoption in water purification systems.



(B)

Figure 1. (A) Separation efficiencies of Microcystis aeruginosa via flocculation – dissolved air flotation (DAF) with varying flocculant dose from 0 – 10 mg L^{-1} of pyridinium modified CNCs and (B) Schematic of Pyridinium modified CNCs

[1] Tyagi, S., Rao, N.R.H., Thielemans, W. et al. Comparing sedimentation and dissolved air flotation for microalgae harvesting: Influence of ionic strength on floc size and separation efficiency. *J Appl Phycol* (**2024**) https://doi.org/10.1007/s10811-024-03385-w

Parallel session 25 - Chemistry, Biology & Physics

2025-08-27
13:50 - 15:10
Parallel session 25 - Chemistry, Biology & Physics

O25.1 - Sustainable approaches to facilitate cellulose fibrillation

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Sustainable approaches to facilitate cellulose fibrillation

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Cellulose nanofibers (CNF) have attracted much attention in the last years due to their excellent properties including high aspect ratio, high strength and stiffness, low density, transparency, and low thermal expansion.[1,2] Despite their outstanding properties, cellulose fibers require much energy to disintegrate them into fine fragments. Another bottleneck on the commercialization of CNF relies on the ability to adapt their properties to industrial applications. For most of the applications, the functionalization of CNF requires chemical modifications after fibrillation, which generally increases costs and environmental impact.

In previous studies we presented the possibility to introduce two functionalities at the cellulose surface in a 1-h one-pot reaction:[3] (i) negative charge that facilitate fibrillation, and (ii) benzophenone groups that allow polymerization and hydrophobization. However, reaction involved toxic chemicals (monochloroacetic acid and sodium hydroxide).

This study reports the impact of phenolic acid functionalization of cellulosic pulps as a strategy to facilitate fibrillation. The functionalization with phenolic acids did not increase the surface charge in a great extent compared to 2,2,6.6-tetramethylpiperidine-1-oxyl (TEMPO) oxidation or carboxymethylation. Nevertheless, the reaction significantly reduced the fiber width and facilitated the fiber disruption under magnetic stirring. Indeed, the reaction increased the fiber accessibility to solvents and enzymes, which boosted fibrillation to prepare cellulose nanofibers.

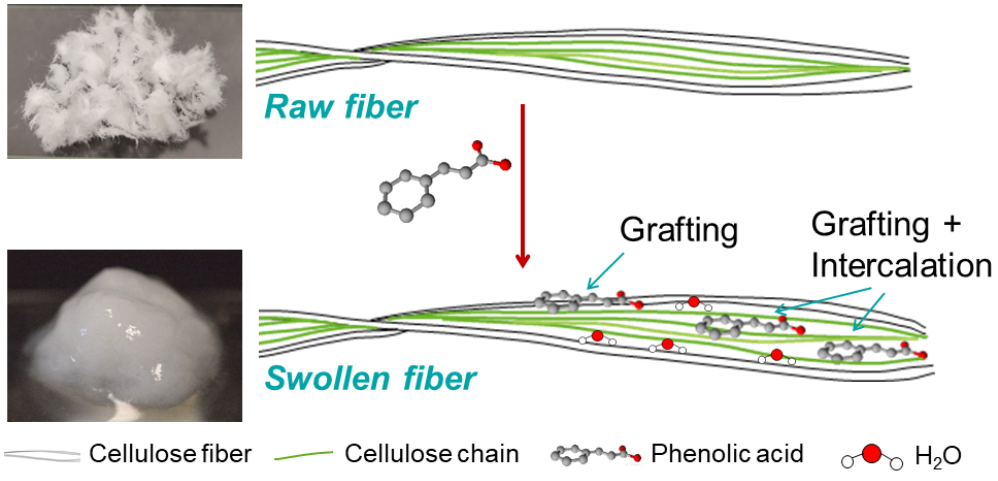

Figure 1. Scheme of the effect of phenolic acids on the cellulose fiber

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O25.2 - ELUTION REVOLUTION: REVERSING CHIRAL RECOGNITION BY SWAPPING D- FOR L-CELLULOSE

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

ELUTION REVOLUTION: REVERSING CHIRAL RECOGNITION BY SWAPPING D- FOR L-CELLULOSE

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Chirality is a fundamental feature of most biological processes. While it can be rather readily observed on the molecular level, chirality transfer and thus enantioselective interactions on the macroscopic level are not as well understood. In this work, we not only exploited the inherent chirality of cellulose and utilized its derivatives for the separation of small enantiomeric molecules by high-performance liquid chromatography (HPLC). We also used synthetic L-cellulose instead of the natural D-glucose-based polysaccharide to create the enantiomeric counterpart (= the molecular mirror image) of conventional chiral selectors based on natural cellulose. By employing phenyl-carbamate derivatives of this synthetic enantiomer of cellulose, we confirmed for the first time the inversion of the analyte elution order by exchanging D- for L-cellulose in this setup. The synthetic chiral stationary phases based on both, D- and L-glucopyranose repeating units were evaluated regarding their enantioseparation behavior and compared to their aliquots derived from the natural biopolymer using a set of representative test analytes. In this way, structure-property relationships and molecular interactions upon enantioseparation were derived. Using equimolar mixtures of L- and D-cellulose derivatives as the chiral stationary phase, we further demonstrated complete cancellation of the chiral separation. These findings contribute to the fundamental understanding of the overall separation mechanism of cellulose-based chiral selectors on both the molecular and supramolecular levels. Our results emphasize the importance of the hierarchical chirality of these chiral stationary phases.

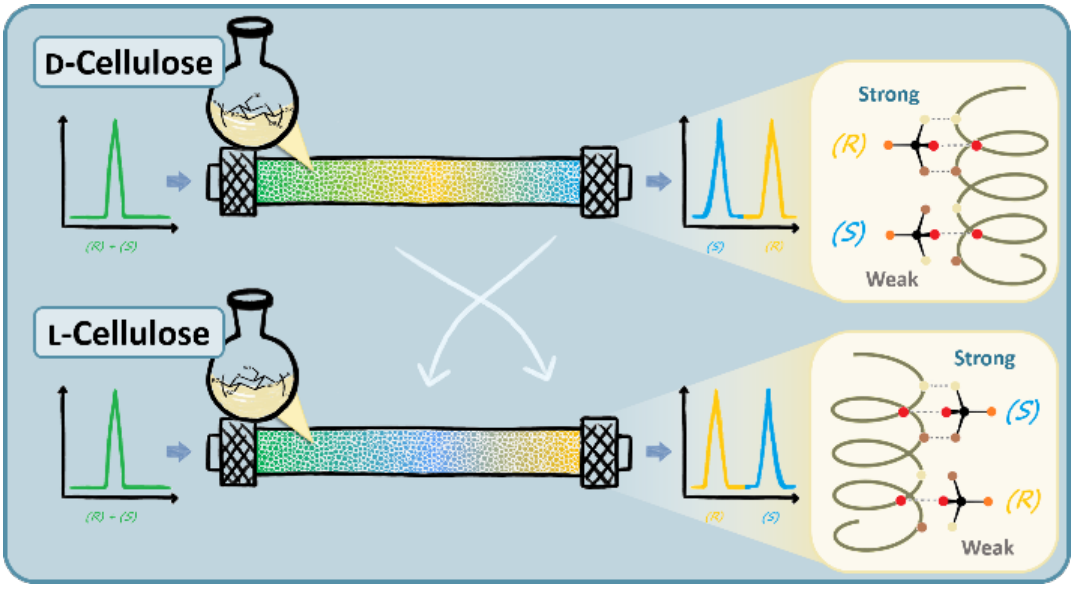

Figure 1. Swapping natural D- for synthetic L-cellulose proves that supramolecular chiral interactions are governed by molecular chirality as demonstrated by chiral HPLC.

O25.3 - EXPLORING THE ORIGIN OF CHIRALITY IN THE CHOLESTERIC PHASES OF CELLULOSE NANOCRYSTALS

Polysaccharide Colloids
Chemistry, Biology & Physics

Exploring the origin of chirality in the cholesteric phases of cellulose nanocrystals

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Cellulose nanocrystals are rod-shaped nanoparticles (approx. 6x150 nm) obtained by acid hydrolysis of cellulose. Colloidally stable due to their surface charge, they are widely studied for their mechanical properties, durability and flexible surface chemistry, but also for their ability to spontaneously self-organise above a critical concentration into a chiral nematic liquid crystal phase, called the cholesteric phase. While the formation of a nematic phase is well modelled by Onsager's theory, the origin of the chirality of the cholesteric phase remains open to debate. In this study, we systematically studied the circular dichroism (CD) signature of the glucose unit in the cholesteric phase of CNCs (see Figure 1) correlated with different states of organisation by varying their concentration, size, and degree of organization. The results presented were obtained by the innovative use of CD on polysaccharides on the DISCO beamline of the SOLEIL synchrotron, exploiting the autofluorescence of these molecules in the UV region of the spectrum.

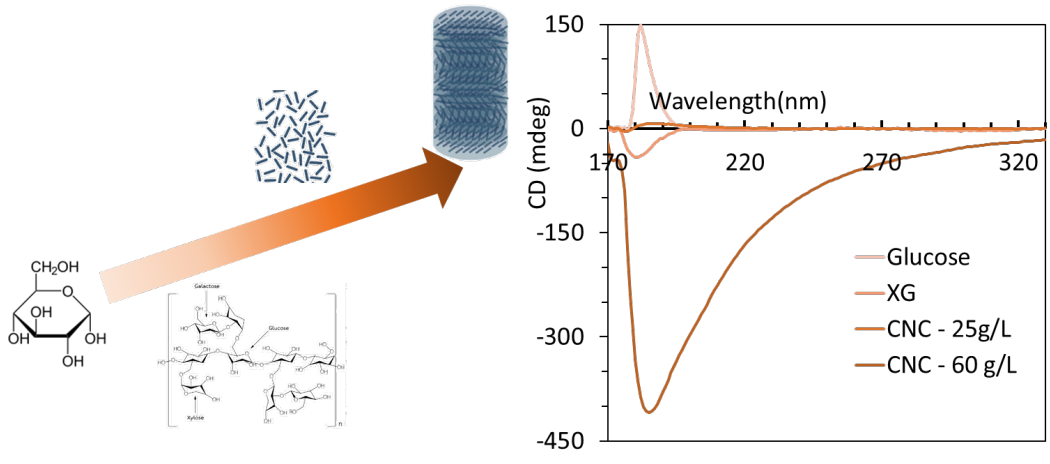

Figure 1 Increasing complexity of the object studied (glucose, xyloglucan chain, isotropic suspension of CNCs, cholesteric suspension) and associated CD signatures

Voisin, H.; Bonnin, E.; Cousin, F.; Capron, I.. *Cellulose* **(2023)**, 1–15.

O25.4 - WOOD XYLANS IN WATER AND DMSO – COLLOIDAL STABILITY, AGGREGATION, AND SOLUBILITY

Chemistry, Biology & Physics

Wood xylans in water anD DMSO – colloidal stability, aggregation, and solubility

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Xylans are an important component in plants and can be isolated through chemical, mechanical and hydrothermal processes. The structure of the isolates depends on the plant source and the process condition. Most xylan isolates are considered water-soluble polysaccharides owing to their hydrophilic structure. However, in practise, the observations of solubility and insolubility are diverse, and indeed the extent of water solubility has been traced down to depend on the chain length and branching.

Being able to predict and alter xylan solubility and properties in solvents would benefit in the development of ways to valorize these biostreams. After all, solubility is decisive, for example, in derivatization, in casting or extruding materials like films and membranes, and in conversions of these sugars to fuels and chemicals.

We have investigated xylans, that have a fraction of neutral (3-10%) and acidic side groups (3-7 %), in water and in dimethyl sulfoxide (DMSO) under the influence of concentration and pH in water-based dispersion and concentration in DMSO- based dispersions. Zeta potential and turbiscan stability index were used as dispersion stability indication highligting especially the role of acidic side groups. We have then addressed aggregation via neutron scattering investigations providing evidence that the xylans intrinsically tend to aggregate even after derivatization [1,2] that improves solubility on other polysaccharides, such as cellulose. These fundamental findings are essential for us, and we believe them to be essential also to the wider community, in adapting to the analytical challenges in quantifying xylan properties as well as in understanding the pathways to exploitation to valorize these biomass streams.

[1] Palasingh C.; Kargl R.; Stana Kleinschek S.; Schaubeder J.; Spirk S.; Ström A.; Nypelö T. *Carbohydr. Polym.* **2023**, *313*, 120810. https://doi.org/10.1016/j.carbpol.2023.120810

[2] Palasingh, C.; Nakayama, K.; Abik, F.; Mikkonen, K.S.; Evenäs, L.; Ström, A.; Nypelö, T. *Carbohydr. Polym.* **2022**, 119660. https://doi.org/10.1016/j.carbpol.2022.119660

Parallel session 26 - Biomedical & Well-Being Applications

2025-08-27
13:50 - 15:10
Parallel session 26 - Biomedical & Well-Being Applications

O26.1 - DESIGN OF HYALURONIC ACID-LIKE POLYSACCHARIDE STABILIZED COSMETIC EMULSIONS CONTAINING ASCORBIC ACID

Cosmetics & Skincare
Biomedical & Well-being Applications

Design of Hyaluronic acid-Like polysaccharide stabilized Cosmetic Emulsions containing Ascorbic Acid

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Hyaluronic acid (HA) is a glycosaminoglycan (GAG) increasingly used for cosmetic applications due its hygroscopicity and biocompatibility. However, HA most common production lacks process efficiency and relies on the use of pathogens such has *Streptococcus zooepidemicus*, bringing safety concerns [1]. In this context, the non-pathogenic strain *Vibrio alginolyticus* Mo245 arises as a potential to be an alternative given its ability to secrete a HA-like extracellular polysaccharide (HA-like EPS), with similar composition, and possessing gelling and viscoelastic properties [2]. In this study, *V. alginolyticus* Mo245 was cultivated to produce the HA-like EPS, which was used for the design of cosmetic emulsions incorporating the water-soluble antioxidant agent ascorbic acid. The secreted HA-like EPS, mainly composed of equimolar amounts of amino sugars and uronic acids, had a high average molecular weight (2.01±0.01 x 10^6 Da), similar to HA [3]. The emulsifying capacity of the Mo245 HA-like EPS for the development of oil-water (O/W) emulsions using castor oil was demonstrated, based on its high emulsification index (EI) (100%) and stability (70% over a period of 30 days). Aiming to define the ingredients' contents for enhanced emulsification and rheological properties towards the development of cosmetic formulations, Response Surface Methodology (RSM) was used to optimize emulsion of the HA-like EPS with castor oil and ascorbic acid. The RSM model established that, for an ascorbic acid content of 11%, optimal emulsification (above 50 %) was attained for HA-like EPS and castor oil concentrations from 1.1 wt% and 10 wt%, respectively. Maximum EI was achieved at HA-like EPS and castor oil concentrations of 1.9 wt% and 30 wt%, respectively. This study demonstrated the promising features of the HA-like EPS produced by *Vibrio alginolyticus* Mo245 as a potential alternative to conventional emulsifiers, rendering it highly appealing for the development of cosmetic formulations.

1. Liu, L., Liu, Y., Li, J., Du, G., & Chen, J. (2011). Microbial production of hyaluronic acid: current state, challenges, and perspectives. Microbial Cell Factories, 10(1), 1-9.

2. Martin-Pastor, M., Ferreira, A. S., Moppert, X., Nunes, C., Coimbra, M. A., Reis, R. L., ... & Novoa Carballal, R. (2019). Structure, rheology, and copper-complexation of a hyaluronan-like exopolysaccharide from *Vibrio*. Carbohydrate polymers, 222, 114999.

3. Juncan, A. M., Morgovan, C., Rus, L. L., & Loghin, F. (2023). Development and Evaluation of a Novel Anti-Ageing Cream Based on Hyaluronic Acid and Other Innovative Cosmetic Actives. Polymers, 15(20), 4134.

O26.2 - Biodegradable guar gum derivatives as rheology modifiers and emulsifiers

Cosmetics & Skincare
Biomedical & Well-being Applications

BIODEGRADABLE GUAR GUM DERIVATIVES AS RHEOLOGY MODIFIERS AND EMULSIFIERS

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The personal care industry is increasingly shifting its focus toward natural-derived and biodegradable products to minimize environmental impact and meet consumer demand for sustainability (*1*). Polysaccharides are common in cosmetic production, primarly as thickening agents; however, they often fall short compared to synthetic alternatives such as polyacrylate polymers (*2*). Their performances can be enhanced through chemical modification (*3*).

In this work, low molar mass guar gum was oxidized with sodium periodate, and the resulting aldehyde groups were functionalised with primary amines to generate imine intermediates, which were finally reduced with sodium borohydride. The reaction with ethanolamine generated a compound (GG $N_1C_2O_1$) with gelling ability upon heating and subsequent cooling, attributed to the introduction of water-binding hydroxylic groups. An inversion of viscoelastic moduli and increase of the elasticity was observed both with a high degree of substitution (DS) (0.08) at 5% (w/w) concentration in DI water and with a lower DS (0.05) at a 7.5% (w/w) concentration (Figure 1a). Materials resulting from the reaction of guar gum with hexylamine (GG N_1C_6) with DS values of ~0.03 formed more structured and elastic systems at 5% and 7.5% (w/w) concentration, likely thanks to hydrophobic interactions (Figure 1b). In contrast, the product with DS 0.05, due to its higher hydrophobicity, failed to form gel in water but could emulsify up to 25% (w/w) of the oily phase. Materials with DS 0.03 could incorporate oils up to 10% (w/w), forming emulsions with mean droplet sizes of 0.95 µm or 0.45 µm, as measured by optical microscopy or dynamic light scattering, respectively. Both GG N_1C_6 (DS 0.08) and GG $N_1C_2O_1$ (DS 0.05) were readily biodegradable, as assessed by OCED 301-F test (*4*).

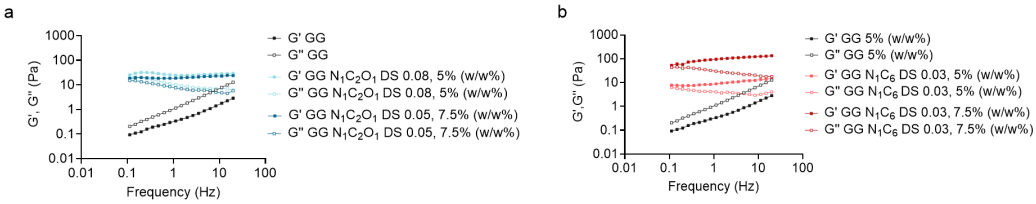

Figure 3 **Figure 1. Frequency sweep analysis of (a) guar gum modified with ethanolamine and (b) guar gum modified with hexylamine compared to unmodified GG.**

In conclusion, thanks to their dual structuring and emulsifying properties, low-substituted hexylamine guar gum derivatives showed great potential as materials for water-based biodegradable cosmetic formulations, and also for water-oils mixture.

1. N. Amberg, C. Fogarassy, *Resources*. **8**, 137 (2019).

2. G. Tafuro, *et al.*, *ACS Omega*. **5**, 15280–15289 (2020).

3. N. do Nascimento Marques *et al.*, in *Emerging Research in Science and Engineering Based on Advanced Experimental and Computational Strategies*, pp. 433–472.

4. *Revised Introduction to the OECD Guidelines for Testing of Chemicals, Section 3* (2006).

O26.3 - New Powder Polymer For 100% Bio-based Cosmetic Formulations

Cosmetics & Skincare
Biomedical & Well-being Applications

New Powder Polymer For 100% Bio-based Cosmetic Formulations

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This study addresses the increasing market demand for natural and environmentally friendly cosmetic formulations. Current trends favor responsible excipients derived from biosourced raw materials with eco-responsible exploitation and low-energy processing. A significant challenge exists in developing bio-based rheology modifiers with performance comparable to synthetic polymers like polyacrylates. While natural polymers such as hydrocolloids, polysaccharides, and proteins possess thickening and stabilizing properties, they often exhibit lower thickening power and formulation difficulties compared to petroleum-based polymers [1].

To bridge this gap, strategies are explored to improve the properties of natural polymers by modifying their chemical structure and therefore their properties in cosmetic formulations.

This research focuses on cross-linking of polysaccharides by using environmentally friendly reactants and processes [2]. In particular, a novel method for crosslinking Xanthan gum is explored, enabling the isolation of the chemically modified polymer in a highly concentrated powder form (exceeding 90%).

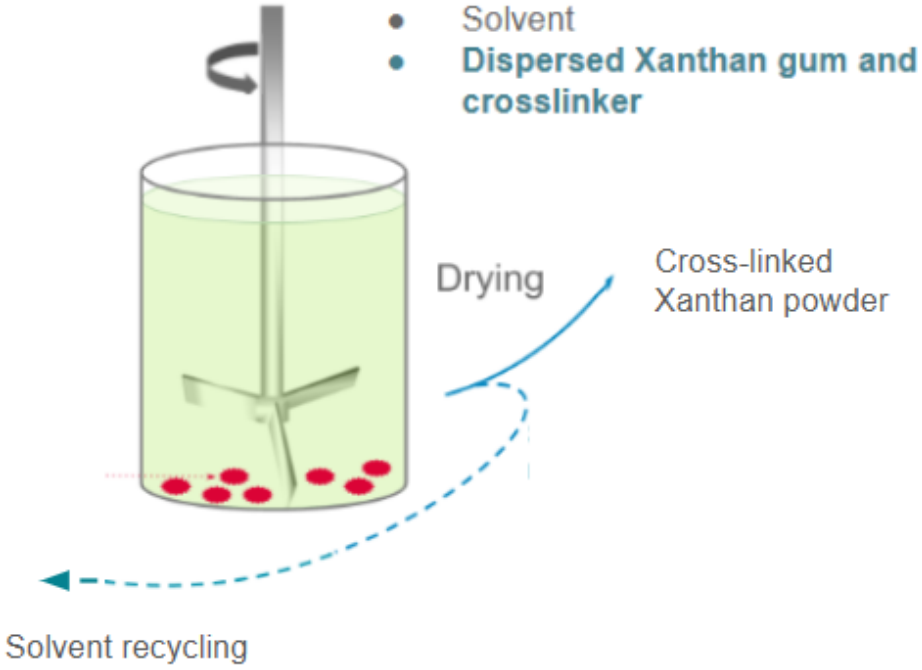

Figure 1:Polysaccharide crosslinking process

The impact of various process parameters on the final product properties is examined.

[1] Glass J.E.; Advances in Chemistry series 223, American Chemical Society, Washington D.C, 1989.

[2] Azerdo H.M.C.; Waldron K., W.; *Trends in Food Science & Technology*. ***2016***, *vol 52,* page 109-122.

O26.4 - Sustainable Valorization of Algal Side-Streams for Cosmetic Applications

Cosmetics & Skincare
Biomedical & Well-being Applications

Sustainable Valorization of Algal Side-Streams for Cosmetic Applications

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Algae-derived products are gaining prominence as versatile sources of biopolymers and bioactive compounds for food, feed, pharmaceutical, and cosmetic applications. While industrial extraction primarily targets phycocolloids (alginate, agar, fucoidan) from macroalgae and proteins or lipids from microalgae, significant side-streams remain underexploited [1,2]. These residual biomasses—rich in valuable components such as polysaccharides and bioactives—offer untapped potential for sustainable revalorization.

Within the CIRCALGAE Horizon Europe project, we explored the valorization of industrial side-streams from *Laminaria hyperborea* (brown macroalga), *Gelidium sesquipedale* (red macroalga), and *Nannochloropsis gaditana* (microalga) using subcritical water extraction (SWE). This green extraction technique, applied for the first time to these algal residues, was optimized via a Central Composite Design (2^3 model). SWE enabled not only the recovery of bioactive-rich extracts but also fibrous fractions suitable for downstream cellulose isolation [3].

Comprehensive characterization and formulation studies demonstrated the applicability of both cellulose-rich fractions and bioactive extracts in cosmetic prototypes, highlighting moisturizing, antioxidant, and texturizing functions. These findings reinforce the viability of circular strategies for algal biomass valorization, bridging the gap between industrial side-streams and high-value applications.

This work showcases how integrating green extraction and targeted end-use testing can transform underutilized marine biomass into functional ingredients, aligning with EPNOE's vision of sustainable polysaccharide innovation and resource-efficient bioeconomy development.

[1] Bojorges, H., López-Rubio, A., Martínez-Abad, A., & Fabra, M. J. *Food Hydrocolloids*, 2025,*162*, 110967.

[2] Cebrián-Lloret, V., Martínez-Abad, A., López-Rubio, A., & Martínez-Sanz, M. *Food Hydrocolloids*, 2024, *146*, 109177.

[3] Cebrián-Lloret, V., Metz, M., Martínez-Abad, A., Knutsen, S. H., Ballance, S., López-Rubio, A., & Martínez-Sanz, M. *Algal Research*, 2022, *61*, 102576.

Parallel session 27 - Materials & Engineering

2025-08-27
13:50 - 15:30
Parallel session 27 - Materials & Engineering

O27.1 - IMPROVED TRIBOELECTRIC OUTPUT BY BULK AND SURFACE MODIFICATIONS OF REGENERATED CELLULOSE

Energy Applications
Materials & Engineering

Improved triboelectric output by bulk and surface modifications of regenerated cellulose

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Triboelectric nanogenerators (TENGs) are a type of energy harvesting technology that convert mechanical energy from motion, vibrations, or friction into electrical energy [1]. TENGs present a promising future for self-powered devices, offering a sustainable, flexible, and efficient method for harvesting energy from mechanical movements. Common materials for TENGs include plastics and metals, but regenerated cellulose, a sustainable material, was shown to be an effective positive triboelectric material [2], achieving power outputs exceeding 300 W m^{-2} [3].

In this study we tried to boost the triboelectric output even further by modifying the surface and bulk of the regenerated cellulose. Surface modifications involved Atomic Layer Deposition (ALD) of the metal oxides Al_2O_3, TiO_2 and ZnO using two different coverages; island like and full coverage. The bulk modifications included graphene additions from 1 wt% up to 33 wt%, where the graphene particles were mixed into the cellulose solution before the regeneration step. This was the most effective modification where a graphene content of 17 wt% increased the power output by 43%. The island like ALD also resulted in an increase in power output, where ZnO was most efficient at 20% increase. Full coverage reduced the performance.

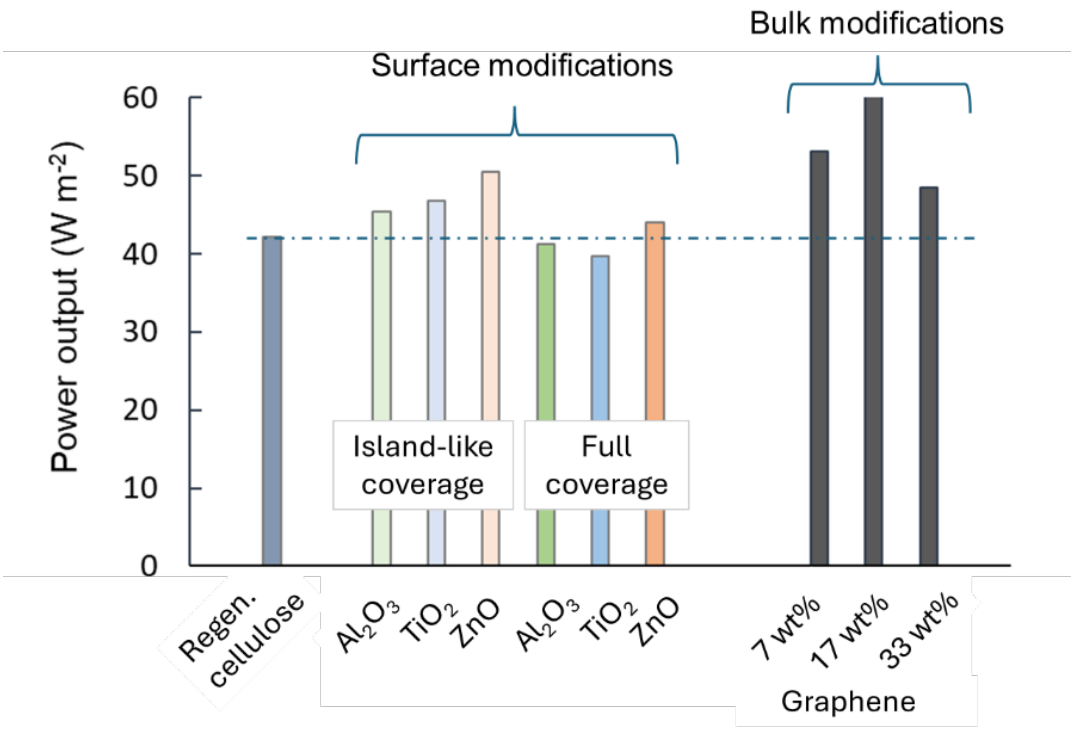

Figure 1. Triboelectric power output for regenerated cellulose and the modified cellulose.

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[2] Dahlström, C. et al. *Cellulose*, **2024**, 31, 2047–2061

[3] Zhang, R. et al. *Advanced Materials*, **2020**, 32, 2002824

O27.2 - NANOCHITIN ENABLED AQUEOUS PROCESSING OF SUSTAINABLE LITHIUM ION BATTERIES

Energy Applications
Materials & Engineering

nANOCHITIN ENABLED AQUEouS PROCESSING OF sustainable Lithium ion batteries

Arumughan, V.*[a], P Sandra, A.[b], Texeria Polez, R.[a], Österberg, M.[a], Lindström, R.[b], Kontturi, E.[a]

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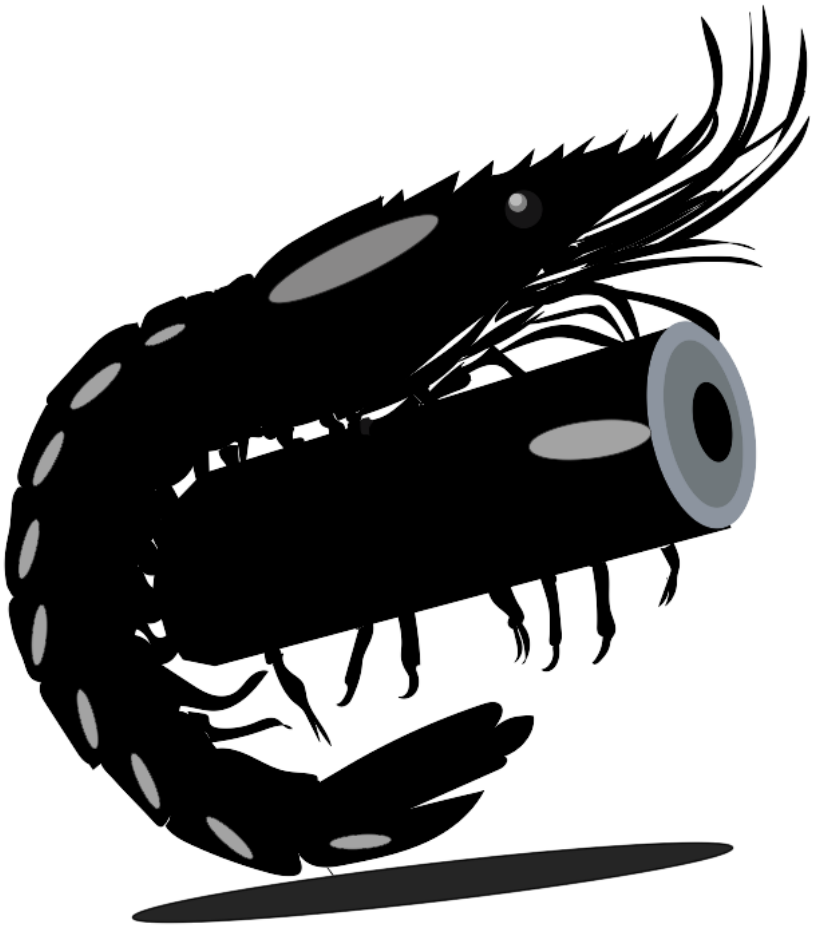
Polymeric binders are a key component in batteries, responsible for holding the active materials together within the electrode [1]. Although they constitute a small fraction of the battery by volume, the choice of binder critically influences the performance, manufacturing process, and recyclability of energy storage systems. Polyvinylidene fluoride (PVDF) is the most commonly used binder, but its use necessitates organic solvent-based processing. Moreover, PVDF is increasingly scrutinized due to environmental concerns and policy changes targeting PFAS compounds. [2]

To address these challenges, we developed a nanochitin-based binder as a sustainable alternative to PVDF. Nanochitin enabled excellent dispersion of graphite in water without the need for additional surfactants. Colloidal probe force microscopy revealed that this exceptional dispersibility arises from cation–π interactions between the chitin nanofibers (ChNFs) and graphite. The resulting ChNF–graphite dispersion exhibited rheological properties suitable for uniform electrode fabrication via blade coating. Electrodes processed entirely in water demonstrated superior electrochemical performance compared to conventional PVDF-based counterparts.



[1] Shi, Ye, Xingyi Zhou, and Guihua Yu. "Material and structural design of novel binder systems for high-energy, high-power lithium-ion batteries." *Accounts of chemical research* 50.11 (2017): 2642-2652.

[2] Bresser, Dominic, et al. "Alternative binders for sustainable electrochemical energy storage–the transition to aqueous electrode processing and bio-derived polymers." Energy & Environmental Science 11.11 (2018): 3096-3127.

O27.3 - OXIDIZED CELLULOSE FOR BINDER APPLICATION IN SILICON ANODE MATERIALS FOR LITHIUM-ION BATTERIES

Energy Applications
Materials & Engineering

Oxidized cellulose for binder application in silicon anode materials for lithium-ion batteries

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Silicon (Si) is a highly researched alternative anode material for lithium-ion batteries (LIBs) due to its high theoretical storage capacity, which has the potential to increase the energy of LIBs [1]. Nevertheless, silicon anodes experience significant volumetric change throughout the lithiation and delithiation procedures [2,3]. This causes the anode to break apart and pulverize, and solid electrolyte interface layers develop in a manner that is not ideal. We suggest oxidised cellulose from polysaccharide sources as a suitable binder for silicon anodes in lithium-ion batteries to tackle difficulties such as limited cycle life and quick capacity decrease. Carboxyl groups of oxidised cellulose produce strong hydrogen bonds, hence excellent adhesion with silicon particles and high reversibility that may allow for increased cycle capacity. Two distinct cellulose sources were explored as polymer binders for Si anodes (microcrystalline cellulose and alpha-cellulose) paired with numerous oxidation chemical methods. XRD, FTIR, and NMR spectroscopies were performed to analyse all these oxidised cellulose samples. Laser granulometry, XRD, RAMAN spectroscopy, TGA, SEM, and STEM/EDX were utilised for the silicon samples. Finally, the loading and ball milling time of the slurry for the anode have been studied using CMC binder [4] as a reference for better understanding and improvement of the conditions for higher performance of the electrode material.

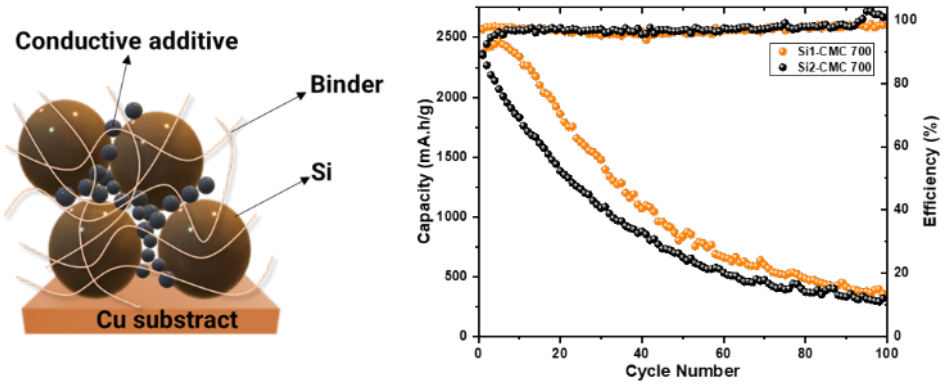

Fig. 1 Oxidized cellulose binder in silicon-based anode for Li-ion batteries

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[3] Hatchard, T. D.; Dahn, J. R.. *J. Electrochem. Soc.* **2004**, *151 (6)*, A838. https://doi.org/10.1149/1.1739217.

[4] NDour, M.; Bonnet, J.-P.; Cavalaglio, S.; Lombard, T.; Courty, M.; Aymard, L.; Przybylski, C.; Bonnet V. *Materials Advances*, **2022**, *3 (23)*, 8522-8533, 10.1039/D2MA00702A,

O27.4 - Wood Luminescent Solar Concentrator

Energy Applications
Materials & Engineering

Wood luminescent solar concentrator

Vivas Glaser, D.*[a], Clemens, S.[a], Ritter, M.[a], Kindler, R.[a], Panzarasa, G.[a]

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The increased use of photovoltaics brings unintended negative impacts on land use, material consumption, and waste generation. Luminescent Solar Concentrators (LSCs), which consist of luminophore-doped slabs with solar cells attached to the edges, have potential to address these issues. LSCs absorb direct and indirect sunlight, concentrate it, and convert it to longer wavelengths to enhance solar cell efficiency. However, improving the efficiency and sustainability of LSCs remains an open challenge, which we have tackled with a novel luminescent Transparent Wood (TW), composed of a cellulose scaffold impregnated with refractive index matching poly(methyl methacrylate) and tailored fluorophores.

A proof-of-concept wood LSC has been obtained and thoroughly analyzed. By functionalizing TW with Aggregation Induced Emission luminogens (AIEgens), we have been able to introduce fluorophores with a concentration of 2500 μM without aggregation caused quenching. The concentration was optimized analyzing the inner filter effects and the dependency of emission on fiber direction. Fluorescent microscopy confirmed the homogeneous impregnation of the scaffold. The LSCs were then attached to solar cells to assess their performance.

A critical prospective Life Cycle Assessment (LCA) pinpointed the delignification and polymerization processes as major contributors to the environmental impact of the wood LSC. However, the LCA sensitivity analysis identified key steps to be taken to reduce the environmental impact.

Thus, our wood-LSC demonstrates promising potential for sustainable solar energy harvesting.

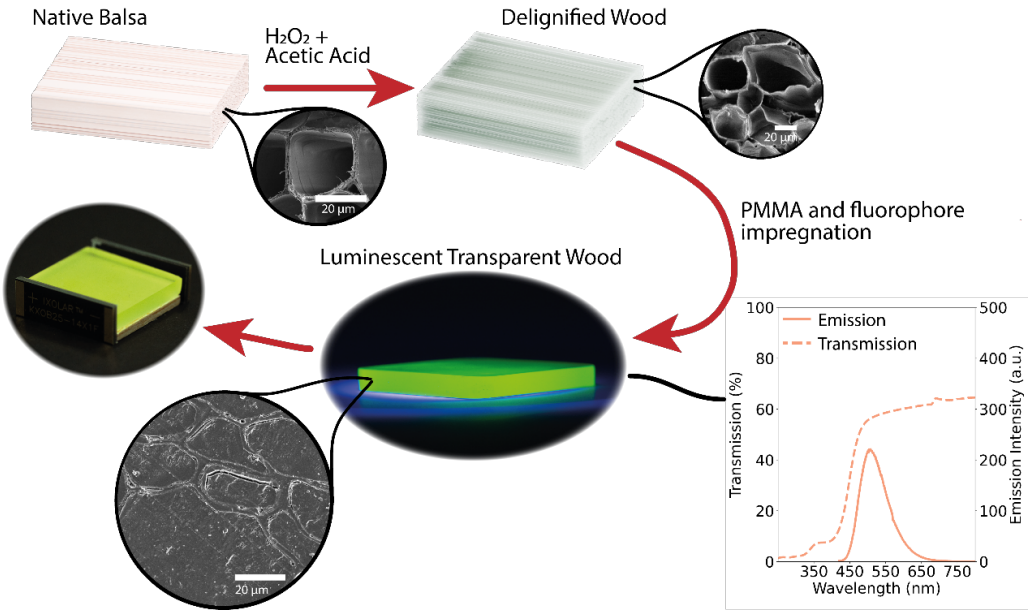

Figure 4 **Figure 1 – Luminescent Transparent Wood (TW) graphical abstract, with a 200 µM AIEgen functionalized TW sample. UV-VIS transmission and spectrofluorometer emission intensity are shown in the bottom right plot.**

O27.5 - BIOBASED MATERIALS AS MEMBRANES IN FLOW BATTERIES AND BEYOND

Energy Applications
Materials & Engineering

Biobased materials as membranes in FLOW BAtteries and beyond

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Ion exchange membranes are key to many industrial applications such as water purification, gas separation, or catalysis, while in energy storage and conversions systems such as fuel cells and flow batteries they additionally serve as physical barrier to avoid short circuits. In these applications, perfluoroalkylsulfonates (Nafion-type) have been used for decades as they are excellent ion exchangers while being chemically very stable. However, while being expensive, the production and end-of life of these membranes create environmental and human health concerns as they are not biodegradable and therefore enrich in soil water and finally in the human body. Here, we demonstrate that cellulose based substrates can be used to potentially replace these Nafion type membranes. The membranes are equipped with effective ion conductors (e.g. ionic liquids) and can be subsequently applied in redox flow batteries and beyond. Our results demonstrate that the membranes have good ionic conductivity enabling its use in both organic and inorganic flow batteries. An organic flow battery was operated for more than 800 cycles and an all-vanadium flow battery for 50 cycles without any loss in ion exchange capacity. The membranes were characterized by a variety of techniques such as scanning electron microscopy (SEM), electrochemical impedance spectroscopy (EIS), and solid-state NMR spectroscopy.

Parallel session 28 - Materials & Engineering

2025-08-27
13:50 - 15:30
Parallel session 28 - Materials & Engineering

O28.1 - REMOVAL OF CHROMIUM(VI) AND CHROMIUM(III) FROM WATER VIA IONIC NANOCELLULOSE AEROGELS

Environmental Remediation
Materials & Engineering

Removal of Chromium(VI) and Chromium(III) from Water VIA Ionic Nanocellulose AEROGELS

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The discharge of trivalent and/or hexavalent chromium in industrial wastewater effluents is linked with severe environmental risks [1]. Removal strategies relying on ionic exchange are not straightforward, due to chromium's complex speciation. On one hand, waterborne Cr(III) typically occurs as cationic species (*e.g.*, Cr^{3+} , $[Cr(OH)_2)]^+$) or as insoluble hydroxides, depending on the pH. On the other hand, Cr(VI) primarily exists as oxyanions: $Cr_2O_7^{2-}$, $HCrO_4^-$, $CrO4^{2-}$. In light of this, this study explores cationic cellulose nanofibers (CCNFs) for Cr(VI) removal and anionic cellulose nanofibers (ACNFs) for Cr(III). Both CCNFs and ACNFs were prepared from bleached eucalyptus kraft pulp via etherification with CHPTAC [2] and by TEMPO-mediated oxidation, respectively [3]. The modified fibers in each case were processed by high-pressure homogenization, mixed with alkyl ketene dimer (AKD), and freeze-dried, resulting in cationic and anionic nanocellulose aerogels. The adsorption of Cr(III) and Cr(VI) was tested both in batch and continuous operations.

CCNFs attained an adsorption capacity of 46 ± 5 mg Cr(VI)/g under optimal conditions, *i.e.*, pH 2 and 0,5 wt% AKD. However, the adsorbate was partially reduced from Cr(VI) to Cr(III). The latter species, in turn, was adsorbed onto ACNFs, but reaching lower capacities —specifically, 13 ± 1 mg Cr(III)/g at pH 3.5. Furthermore, while adsorption isotherms of Cr(VI) could be consistently fitted to a Freundlich model (Figure 1), a Langmuir model was better to describe the adsorption of Cr(III) onto ACNF aerogels.

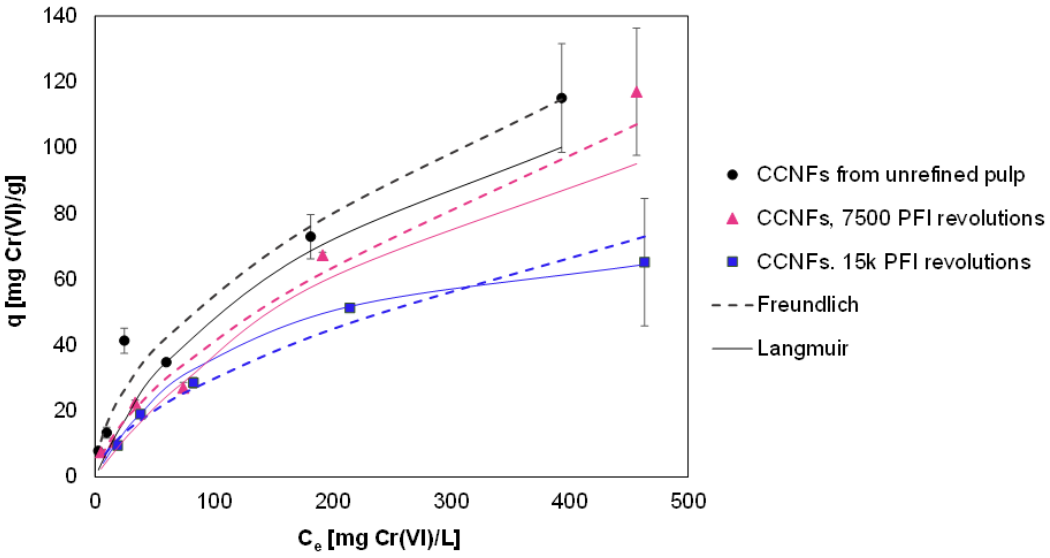

Figure 1. Adsorption isotherms of Cr(VI) onto CCNFs produced from unrefined pulp and from pulp refined to 7500 or 15000 PFI revolutions. Temperature: 23 °C.

[1] Prasad, S.; Yadav, K.K.; Kumar, S. ... Alam, J. *J. Environ. Manag.* **2021**, *285*, 112174

[2] Aguado, R.; Moral, A.; Tijero, A. *J. Clean. Prod.* **2018**, *174*, 1503-1512

[3] Mazega, A.; Lehrhofer, A.F.; Aguado, R.J. … Delgado-Aguilar, M. *Cellulose* **2025**, *32*

O28.2 - NANOCELLULOSE-BASED CRYOGELS FOR WATER REMEDIATION

Environmental Remediation
Materials & Engineering

Nanocellulose-based cryogels for water remediation

Lorevice, M.V.[a], Aleixo, N. A.[a,b], Claro, P. I. C.[a], **Gouveia, R. F.[a,b*]**

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The increasing demand for eco-friendly water remediation solutions has amplified interest in nanocellulose-based cryogels, specially using cellulose nanofibrils (CNFs), which provide advantages such as high porosity, large surface area, low density, renewability, and biodegradability. Nonetheless, the inherent hydrophilicity of cellulose often necessitates chemical crosslinking to achieve structural integrity and water resistance [1]. In this study, we introduce a solvent-free method to fabricate water-resistant cryogels by combining different CNF nanoestructures with natural rubber latex (NRL) [2,3]. Figure 1a shows a highly porous cryogel obtained by X ray microtomography [2,4], which exhibits adjustable properties, including high porosity (92%), a high specific surface area of approximately 226 $m^2 \cdot g^{-1}$, an interconnected (Figure 1b) micro-to-nanoporous 3D structure, and mechanical robustness (Young's modulus ~400 kPa). The nanocellulose-based cryogels show absorption capacities for organic solvents and oils (*e.g.* 50 $g.g^{-1}$), as well as adsorption performance for heavy metals, ranging from 100 to 400 $mg \cdot g^{-1}$ for Cu^{2+}, demonstrating excellent tunable capacities and reusability. Scanning electron microscopy showed that NRL is well distributed in the porous wall (Figure 1c). Importantly, ecotoxicity assessments indicated that CNF/NRL not only remediates Cu^{2+}-contaminated water without harming *Daphnia similis* but is also inherently non-toxic. These results underscore the potential of CNF/NRL as a safe, sustainable, and highly efficient material for environmental remediation applications.

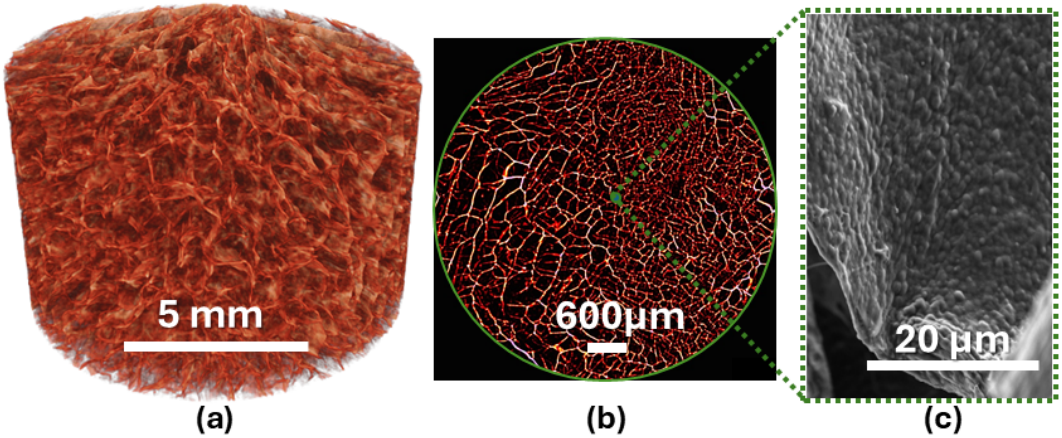

Figure 1. Cellulose nanofibrils and natural rubber latex (CNF/NRL: 80/20 wt%) cryogel. (a) 3D X-ray microtomography. (b) 2D slice. (c) Image of scanning electron microscopy for a pore wall.

[1] Etale, A., Onyianta, A. J., Turner, S. R. & Eichhorn, S. J. *Chem Rev* **2023**, 123, 2016.

[2] Lorevice, M. V., Claro, P. I. C., Aleixo, N. A., Martins, L. S., Maia, M. T., Oliveira, A. P. S., Martinez, D. S. T., & Gouveia, R. F. *Chem. Eng. J.* **2023**, 462, 142166.

[3] Lorevice, M. V. Mendonça, E. O., Orra, N. M., Borges, A. C. & Gouveia, R. F. *ACS Appl. Nano Mater* **2020**, 3, 10954.

[4] Claro, P. I. C., Borges, E. P. S., Schleder, G. R., Archila, N. L., Pinto, A., Carvalho, M., Driemeier, C. E., Fazzio, A. & Gouveia, R. F. *Appl Phys Rev* **2023**, 10, 021302.

O28.3 - Wastewater treatment with cationized cellulose nanofibres derived from wood fractionation using deep eutectic solvents.

Environmental Remediation
Materials & Engineering

Wastewater treatment with cationized cellulose nanofibres derived from wood fractionation using deep eutectic solvents.

Solange Magalhães[1,2], Jorge Pedrosa[1], Paulo J.T. Ferreira[1], Maria G. Rasteiro[1], Bruno Medronho[2,3], Luís Alves[1,*]

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[3](MED) Mediterranean Institute for Agriculture, Environment and Development), CHANGE (Global Change and Sustainability Institute), Universidade do Algarve, Faculdade de Ciências e Tecnologia, Campus de Gambelas, Ed. 8, 8005-139 Faro, Portugal.

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The selective extraction and recovery of different molecules of interest from lignocellulosic materials from forestry residues are increasing every day driving society towards more sustainable approaches and materials. For this purpose, the development of new sustainable and ecologically benign extraction methodologies has grown significantly. Deep eutectic solvents (DESs) appear as a promising alternative for the processing of biomass. In the present study, binary DES formed using choline chloride and levulinic acid, in different ratios, were studied to fractionate lignocellulosic waste of acacia wood, an invasive species in Portugal. Different parameters, such as temperature and extraction time, were optimized to enhance the yield and purity of the recovered cellulose. The extraction conditions and DES composition revealed a relevant impact on the amount of extracted material and affected the purity and properties of the cellulose extracted. Good extraction yields and purity of the isolated materials were obtained and the lignin content in the cellulose fraction was remarkably low [1, 2].

The obtained cellulose-rich fraction was then used to prepare cationized cellulose nanofibres. To do so, quaternary ammonium groups were added to cellulose fibres, through a direct reaction with 2,3-epoxypropyltrimethylammonium chloride (EPTAC), followed by a physical treatment, high-pressure homogenization. This reaction is able to introduce cationic charges without extensive degradation of cellulose structure. The obtained nanofibres can be used as a novel bio-based flocculant to treat domestic wastewater. The performance of the novel bio-flocculant was compared to traditional coagulants/flocculants [3]. The novel bio-based flocculants represent a novel remarkable finding and a step forward in this knowledge area for waste water treatment.

1. Magalhães, S., et al., *Enhancing Cellulose and Lignin Fractionation from Acacia Wood:*

Optimized Parameters Using a Deep Eutectic Solvent System and Solvent Recovery. Molecules, 2024. **29**(15): p. 3495.

2. Magalhães, S., et al., *Acacia Wood Fractionation Using Deep Eutectic Solvents: Extraction, Recovery, and Characterization of the Different Fractions.* ACS Omega, 2022. **7**(30): p. 26005-26014.

3. Ribau Teixeira, M., et al., *Nanofibrillated cationic cellulose derivatives as flocculants for domestic wastewater treatment.* Journal of Water Process Engineering, 2024. **58**: p. 104817.

O28.4 - MULTIFUNCTIONAL NANOCELLULOSE MEMBRANES WITH SILVER NANOPARTICLES FOR ENHANCED PHOTOCATALYTIC WATER TREATMENT

Environmental Remediation
Materials & Engineering

Multifunctional NAnocellulose Membranes with silver nanoparticles for Enhanced Photocatalytic Water treatment

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This study presents multifunctional cellulose nanofiber (CNF) membranes containing in situ-synthesized silver nanoparticles (AgNP) for the efficient removal of organic pollutants from water. These membranes combine the mechanical strength and adsorption capacity of nanocellulose with the plasmonic properties of AgNPs, which, under blue light irradiation, accelerate the photocatalytic degradation of contaminants such as dyes and antibiotics.

Performance tests demonstrated that CNF_AgNP membranes exhibit higher adsorption and also degradation behavior when irradiated by light. For that, kinetic studies were performed in a photoreactor with blue irradiation (457nm) and under dark conditions in the presence of CNF and CNF_AgNP membranes. The antibiotic Vancomycin was also investigated with the CNF_AgNP membrane under blue light exposure achieving almost 100% removal of vancomycin in 20 min.

In addition to pollutant removal, the membranes showed stability and reusability over multiple cycles while maintaining high efficiency and its integrity. Bacterial tests revealed that exposure of vancomycin to CNF_AgNP membranes under blue light reduced its antimicrobial activity.

These results emphasize the potential of CNF_AgNP membranes as a sustainable solution for water treatment, combining adsorption and plasmonic photocatalysis without the need for additional oxidative agents. This study paves the way for scaling up the application of these membranes, contributing to advanced water purification technologies.

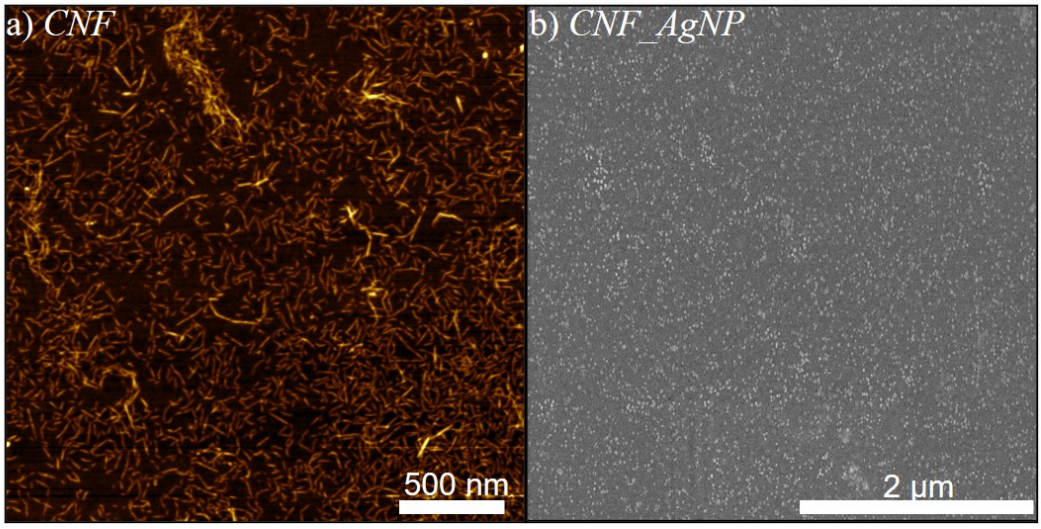

Figure 1. a) Atomic force microscopy image of CNF dispersion in water and b) Scanning electron microscopy image of CNF_AgNP membrane.

O28.5 - CITRIC ACID CROSSLINKED LIGNOCELLULOSIC HYDROGEL BEADS FOR THE REMOVAL OF CHROMIUM FROM WASTEWATER

Environmental Remediation
Materials & Engineering

citric acid crosslinked LIGNOCELLULOSIc hydrogel BEADS FOR THE REMOVAL OF CHROMIUM FROM WASTEWATER

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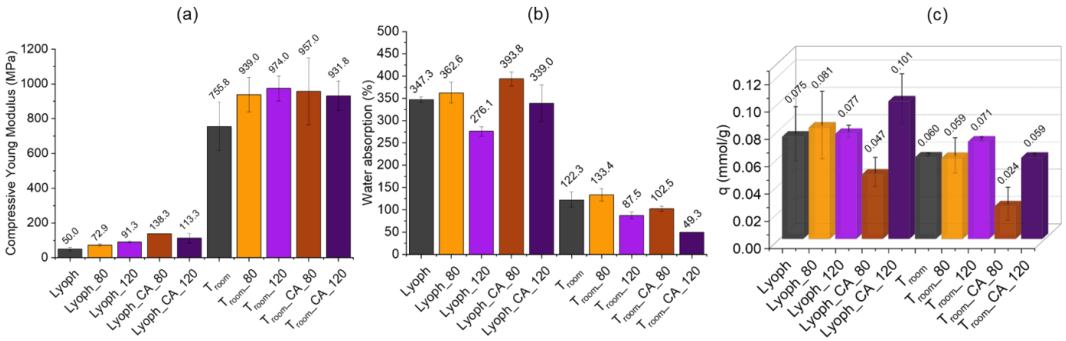
Lignocellulose-based sorbents were evaluated for their effectiveness in removing toxic metals as chromium from industrial wastewaters. A bis(ethylenediamine)-copper(II) hydroxide solution (CUEN) was used to deconstruct sisal fiber and subsequently produce hydrogel beads aimed at removing Cr(VI) from wastewater. The medium composed of dissolved cellulose and hemicelluloses, and suspended lignin, was dropped to a calcium chloride solution to create hydrogel spheres. The dried beads (8 g) (room temperature, or lyophilization) were soaked into 200 mL of citric acid (CA) solution (20 %) and put into an oven at 80 ºC and 120 ºC to promote the crosslinking reaction. The viscosity average molar mass (M_v) of the beads redissolved in CUEN was assessed to evaluate the role of CA in the cellulose chains' hydrolysis. The beads' sorption capacity (q/mmol/g) was obtained by putting the beads in contact with a Cr(VI) aqueous solution (analyzed via UV-VIS spectroscopy). Figure 1 presents the beads compressive Young modulus (a), water swelling (b), and q towards Cr(VI) (c).



Legend

Lyoph – lyophilized **T_{room} – dried at room temperature**

Lyoph_80 – lyophilized and treated at **T_{room}_80 – dried at room temperature and**

80 ºC	**treated at 80 ºC**
Lyoph_120 – lyophilized and treated at 120 ºC	**T_{room}_120 – dried at room temperature and treated at 120 ºC**
Lyoph_CA_80 – lyophilized and crosslinked with CA at 80 ºC	**T_{room}_CA_80 – dried at room temperature and crosslinked with CA at 80 ºC**
Lyoph_CA_120 – lyophilized and crosslinked with CA at 120 ºC	**T_{room}_CA_120 – dried at room temperature and crosslinked with CA at 120 ºC**

Figure 1. Young modulus under compression (a); Water swelling (b); chromium sorption capacity of the beads (c) (C_i = 1 mM, S/L ratio = 1 g/L, T = 25 ºC, time = 24 h, pH = 4.0).

The FTIR spectra indicated that the esterification of the –OH groups only occurred at 120 ºC. The hydrogels' M_v reduced until one magnitude order for the samples crosslinked with CA, which means CA hydrolyzed notably the cellulose chains. CA crosslinking increased the Young's modulus of the freeze-dried beads; however, this effect was not observed in the T_{room} series (Figure 1(a)), despite the latter exhibiting a higher modulus. Figure 1(b) shows that the lyophilization confers a higher water absorption to the beads, due to higher porosity corroborated by SEM images. CA crosslinking of the lyophilized samples had a positive impact on the *q* of Cr(VI) (Figure 1 (c)). This research shows the potential of sisal-based hydrogels crosslinked with CA, for eliminating Cr(VI) from wastewater while adhering to sustainability principles. Funding: São Paulo Research Foundation Brazil (#2023/07447-2), National Council for Scientific and Technological Development, Brazil (403494/2021-4).

Parallel session 29 - Chemistry, Biology & Physics / Materials & Engineering

2025-08-27
15:50 - 17:50
Parallel session 29 - Chemistry, Biology & Physics / Materials & Engineering

O29.1 - Optimization of Chitosan-TPP Nanoparticle Synthesis Using Box-Behnken Experimental Design for Macro and Micronutrient Release

Sustainable Materials/Circular Economy
Materials & Engineering

Optimization of Chitosan-TPP Nanoparticle Synthesis Using Box-Behnken Experimental Design for Macro and Micronutrient Release

Mhamed Berrada[a,b], Taha El Assimi[a,c], Catherine Ladavière[b], Thomas Trimaille[b] , Stephane Trombotto[b], Emmanuel Beyou[b], Mohammed Lahcini[c,d] , Redouane Beniazza[a],

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[b] Université de Lyon, CNRS, Université Claude Bernard Lyon 1, INSA Lyon, Université Jean Monnet, UMR 5223, Ingénierie des Matériaux Polymères, 15 Boulevard Latarjet, 69122, Villeurbanne Cedex, France

[c] IMED-Lab, Faculty of Sciences and Techniques, Cadi Ayyad University, Avenue Abdelkrim Elkhattabi, B.P 549, 40000, Marrakech, Morocco

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Enhancing nutrients use efficiency while minimizing environmental impact is a major challenge in the context of sustainable fertilizations. However, conventional fertilizers often suffer from inefficient nutrient delivery to losses through leaching and runoff, which contribute to environmental pollution. In this study, chitosan-tripolyphosphate (TPP) nanoparticles were developed as a controlled and efficient system of macro- and micronutrients to improve fertilizer efficiency. Chitosan, as a biodegradable and biocompatible polysaccharide, was selected for its ability to form stable nanoparticles through ionotropic gelation. TPP, serving as both a crosslinker and a phosphorus (P) source, facilitating the formation of a structured network capable of impregnating essential nutrients, such as iron (Fe), zinc (Zn), and copper (Cu), ensuring thus prolonged nutrient availability for plant uptake. Besides, A Box-Behnken experimental design was employed to optimize key synthesis parameters, including chitosan-to-TPP ratio, pH, and stirring speed, to achieve nanoparticles with enhanced nutrient impregnation and release properties. Indeed, the optimized nanoparticles enable a controlled and sustained release of nutrients, reducing losses through leaching while ensuring improved plant uptake. Additionally, chitosan's intrinsic antimicrobial properties provide added benefits in protecting crops from soil-borne pathogens, contributing to plant health and productivity.

This study highlights the potential of chitosan-TPP nanoparticles as an innovative and sustainable solution for precision fertilization. By optimizing nutrient delivery, this approach enhances

agricultural productivity while mitigating environmental concerns associated with conventional fertilizers.

O29.2 - EXPLORING MARINE POLYSACCHARIDES AND BIOBASED PLASTICIZERS FOR THE DEVELOPMENT OF NOVEL THERMOPLASTIC BLENDS

Sustainable Materials/Circular Economy
Materials & Engineering

Exploring Marine Polysaccharides and biobased Plasticizers for the development of novel thermoplastic blends

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Conventional petroleum-based plastics are widely used in everyday applications; however, their non-biodegradable nature and consequent persistence in the environment is associated with enormous environmental and health issues.

Biopolymers offer a promising alternative to conventional non-biodegradable petroleum-based plastics as they are bio-based and biodegradable. However, in some cases, their inherent brittleness and high cost limit their industrial application. For example, poly(hydroxybutyrate) (PHB) is the most widely studied poly(hydroxyalkanoate) (PHA) due to its large availability and for being the least expensive PHA. To overcome these limitations, various studies have investigated its blending with other (bio)polymers, including polysaccharides, showing promising results [1,2].

In this context, this study investigates the impact of marine polysaccharide and bio-based plasticizer contents on the properties of novel PHB-based thermoplastic blends (**Figure 1**).

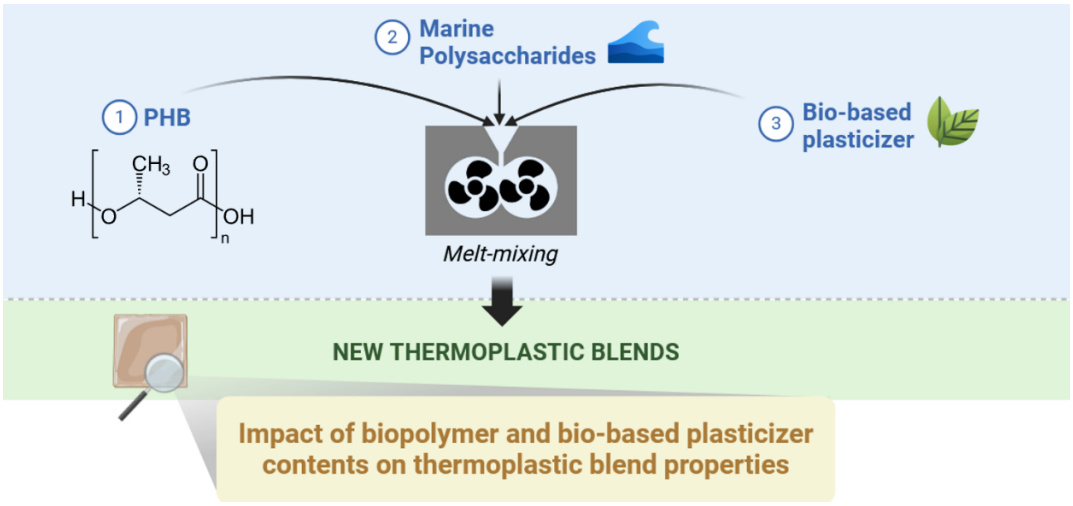

Figure 1. Scheme of the fabrication of novel PHB thermoplastic blends with marine polysaccharides and biobased plasticizers.

[1] Jaffur, B. ; Kumar, G.; Jeetah, P.; Ramakrishna, S.; Bhatia, S., *Int. J. Biol. Macromol.* **2023**, *253.*

[2] Ribeiro Lopes, J.; Azevedo dos Reis, R.; Almeida, L., *J. Appl. Polym. Sci.* **2017**, *134*.

Acknowledgments: This study was funded by the PRR – Plano de Recuperação e Resiliência and by the NextGenerationEU funds at Universidade de Aveiro, through the scope of the Agenda for Business Innovation "Pacto da Bioeconomia Azul" (Project no. 16 with the application no. C644915664-00000026) and the project CICECO–Aveiro Institute of Materials, UIDB/50011/2020 (DOI 10.54499/UIDB/50011/2020), UIDP/50011/2020 (DOI 10.54499/UIDP/50011/2020) & LA/P/0006/2020 (DOI 10.54499/LA/P/0006/2020), financed by national funds through the FCT/MCTES (PIDDAC).

O29.3 - Metal-coordinating engineered nanocellulose as a sustainable heterogeneous catalyst

Nanostructured Materials
Materials & Engineering

metal-coordinating engineered nanocellulose as a sustainable heterogeneous catalyst

Faggioli, E. G.*[a], Nicastro, G.[a], Punta, C.[a], Riva, L.[a], Sacchetti, A.[a]

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In recent years, both industry and academia have strongly pursued the concept of green and sustainable chemistry, especially in the field of catalysis. State-of-art heterogeneous catalysts are currently designed with the environment in mind, aiming at easier recovery, biodegradability and recyclability of all the materials involved [1]. One great option for supporting active molecules are carbohydrate polymers, because of the flexibility they offer in terms of structure [2].

Particularly, cellulose and its nanosized derivatives have been widely investigated as scaffolds for metal nanoparticles (NPs), that nowadays are a widespread method to perform crucial reactions in chemical engineering such as "click" reactions, Suzuki couplings and CO_2 conversion [3]. In fact, NPs are rising as a key player in the field of catalysis thanks to their extremely high surface area and ease of access for reagents [4]. Nonetheless, heterogeneous catalysis presents a significant drawback in the slower reactivity with respect to its homogeneous counterpart due to mass transport limitations in NPs that, while being optimised to ensure the best performances, still don’t quite reach the benchmark of homogeneous catalysts.

To overcome the issues rising from both methodologies, in this work we designed an engineered nanocellulose material able to coordinate a variety of metal ions, avoiding the need of NPs and turning the inert polymeric scaffold into an active participant in the reaction. We extracted cellulose nanofibers (CNFs) with chemical and mechanical methods, and we functionalised them with molecules mimicking those investigated in previous findings of our research group [2], obtaining a stable, mono-material product. Furthermore, we established the reactivity of our homogeneous-inspired heterogeneous catalysts in the coordination of Pd^{2+}, Cu^{2+} and Co^{2+} ions. Results from the application of these materials in aforementioned reactions will be reported, highlighting the potential of a new perspective on nanocellulose-based catalysts.

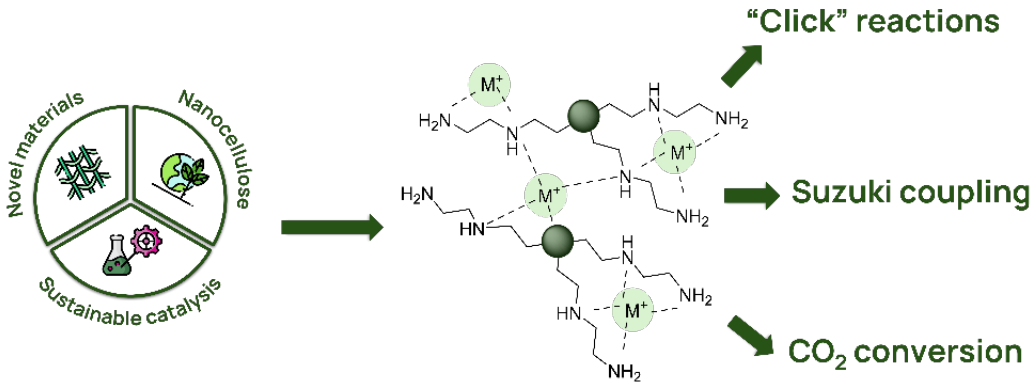

Figure 1. Graphical abstract

[1] Rostami, N.; Dekamin, M. G. et al., *Sci Rep* **2022**, *12* (1), 8642

[2] Riva, L.; Nicastro, G. et al., *Gels* **2022**, *8* (12), 789

[3] Kaushik, M. & Moores, A., *Green Chem.* **2016**, *18* (3), 622–637

[4] Jebali, Z.; Granados, A. et al., *Cellulose* **2018**, *25* (12), 6963–6975

O29.4 - Evidencing entropy as a driving force in hemicellulose-cellulose interactions

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Evidencing ENTROPY as a DRIVING force in hemicellulose-cellulose interactions

Virkkala, T.[a], Grachev, V.[b], Kontturi, E.[c], Thielemans, W.[b], Tammelin, T.[a]

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[b] Sustainable Materials Lab, Department of Chemical Engineering, KU Leuven, Campus Kulak Kortrijk, Etienne Sabbelaan 53, BE-8500 Kortrijk, Belgium.

[c] Department of Bioproducts and Biosystems, Aalto University, FI-00076 Aalto, Finland.

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Despite the importance of hemicellulose and cellulose interactions in understanding the assembly of the plant cell wall in nature and applied materials structures based on these abundant plant-based polysaccharides, several gaps in the knowledge on the mechanisms of the interactions exist. For example, the thermodynamics of interactions between plant cell wall components remain largely unexplored and the existing studies are focused on cellulose and xyloglucan.[1,2] Cereal hemicelluloses, i.e., mixed-linkage glucans (MLGs) possess interesting properties for (nano)cellulose-based materials architectures, such as irreversible interactions with cellulosic substrates[3,4], efficient gelation[5] and hydration of nanocellulose networks[6]. Additionally, nanocellulose networks, which are physically cross-linked with MLGs form mechanically stable and life-sustaining hydrogels for solid-state photosynthetic cell factories[4]. While it is generally known that polysaccharide adsorption on cellulose surfaces is driven by an entropic gain caused by the release of water molecules from the adsorbent and adsorbant surfaces, gaining direct experimental evidence on the driving force of MLG adsorption on cellulose is non-trivial. To this end, we use isothermal titration calorimetry (ITC) in conjuction with quartz crystal microbalance with dissipation monitoring (QCM-D) to study the thermodynamics of MLG and nanocellulose interactions (Figure 1). By directly measuring the heat involved in the interactions and probing the temperature dependency of MLG adsorption, we show that MLG-nanocellulose interactions are indeed attributed to entropic effects.

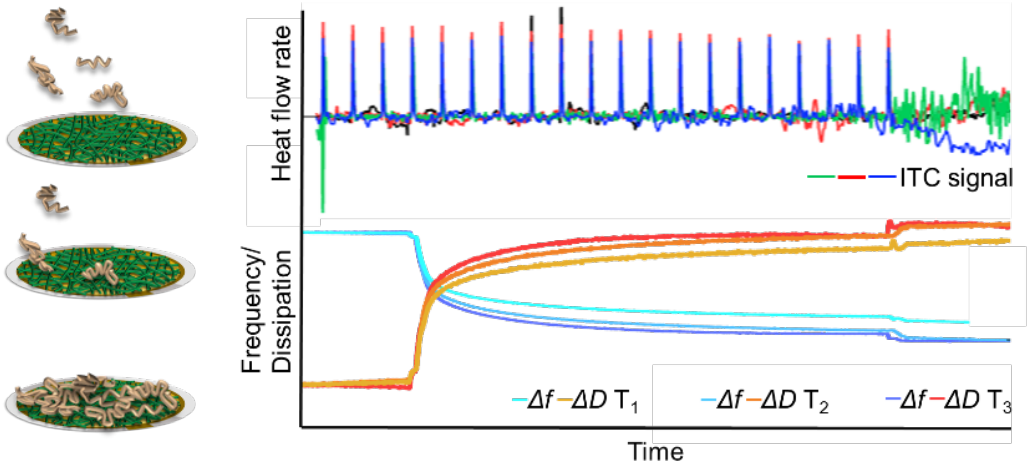

Figure 1. Measuring heat transfer and temperature dependency of MLG-nanocellulose interactions via isothermal titration calorimetry (ITC) and quartz crystal microbalance with dissipation monitoring (QCM-D), respectively.

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O29.5 - Adsorption Mechanisms of Polydopamine on Cellulose Thin Films - A Molecular Dynamics Study

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Adsorption mechanisms of polydopamine on cellulose thin films – a molecular dynamics study

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Recent advances in materials modeling have paved the way for the design of sustainable composites, such as cellulose-based electrospun fibers [1]. In particular, cellulose nanocrystals have proven to be exceptional reinforcements for polymeric matrices in 3D printing applications. Since surfaces and interfaces–especially at the molecular scale– govern critical properties such as **wetting, separation, stability, and reactivity**, there is a growing need for precise strategies to optimize these interactions [2].

Coatings have emerged as an effective approach to enhancing the **interfacial properties** of composite structures. Among them, polydopamine (PD), often referred to as a "universal adhesive," exhibits strong interactions with a wide range of surfaces, regardless of their polarity or reactivity. However, the complexities of PD polymerization, along with the potential cross-linked 3D structures, make it challenging to study experimentally.

The **computation of adsorption free energies** has recently gained prominence in the development of advanced materials, as it enables detailed insights into interfacial interactions and surface modifications [3]. However, these computational techniques are often demanding, requiring significant computational power, which limits their widespread use.

In this work, we investigate the adsorption mechanisms of polydopamine onto different crystalline faces of cellulose Iβ, specifically (200) and (110), and analyze their separation processes. Our results indicate that PD-cellulose adsorption energies are highly dependent on the pull rate, highlighting the need for a more detailed molecular-level investigation of these interfacial interactions.

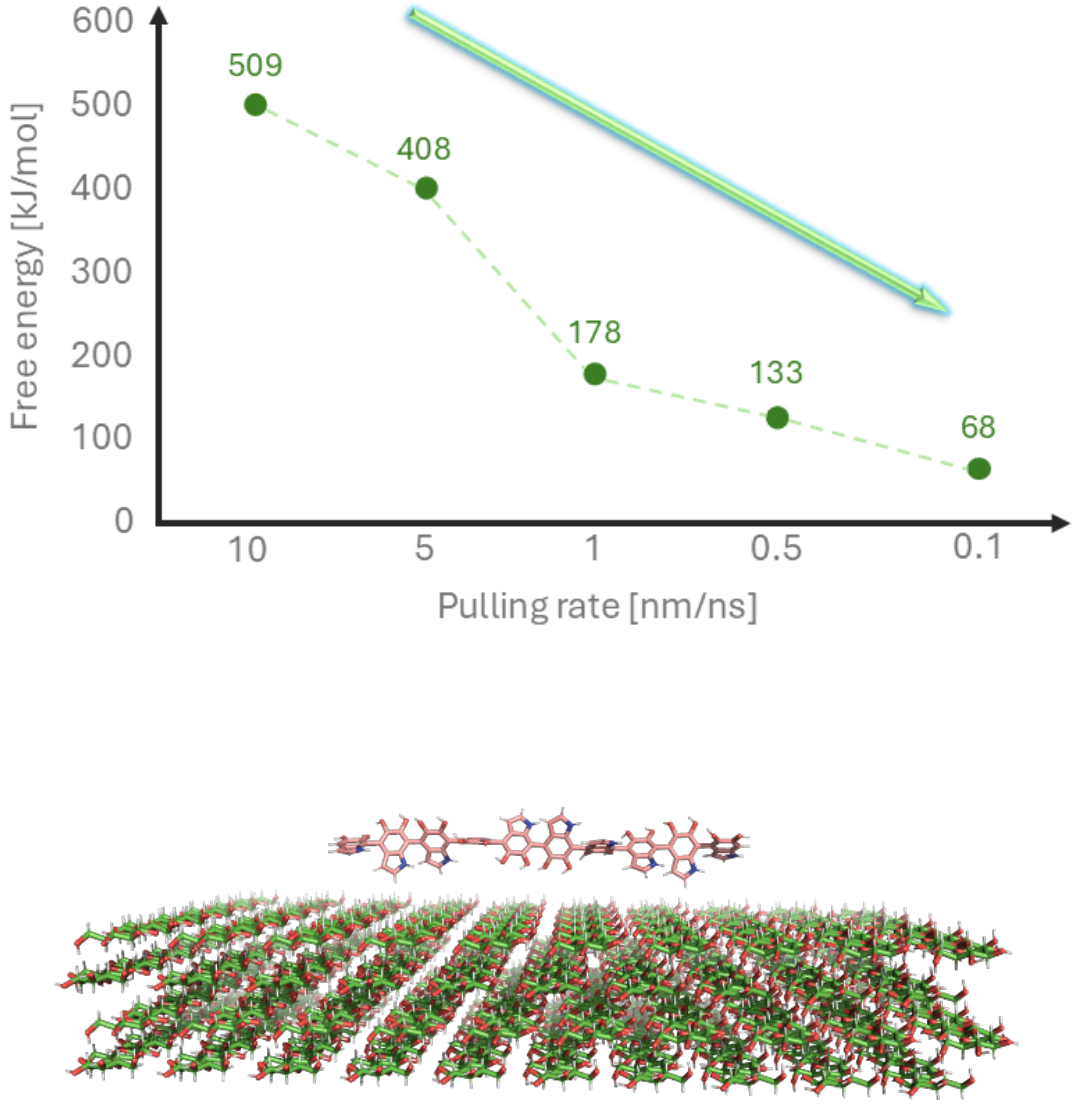

Figure 1. Adsorption free energy of PD-cellulose thin films, decreasing with separation rate.

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Acknowledgments: The authors acknowledge the M-ERA.NET project BioCel3D funded by the Fonds National de la Recherche (FNR) Luxembourg (INTER/MERA21/ 16531229/BioCel3D) and the Research Foundation Flanders (FWO) Belgium (G0K9722N).

O29.6 - Capturing off-flavor compounds in Recirculating aquaculture systems (RAS) with functional cellulose materials

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Capturing off-flavor compounds in Recirculating aquaculture systems (RAS)

with functional cellulose materials

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In this work, a functional cellulose material was developed to capture off-flavor compounds in a pilot-scale recirculating aquaculture system (RAS). Off-flavor compounds are chemical molecules produced by microorganisms in water [1]. These compounds give a "mud-like" flavor to fish, lowering the quality of the product and causing significant economic losses [2]. The capturing of off-flavor compounds is based on functionalized cellulose material that effectively removes formed off-flavor compounds in the pilot-scale RAS tests and thus prevents these compounds from accumulating in fish. The synthesis of the capture material was characterized by scientific measurements. The developed capturing system for off-flavor compounds is a solution for improving RAS-produced fish quality and preventing economic losses.

Figure 1. RAS tank for farming fishes.

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Parallel session 30 - Chemistry, Biology & Physics

2025-08-27
15:50 - 17:50
Parallel session 30 - Chemistry, Biology & Physics

O30.1 - Immobilized enzyme monolithic platform for tailored poly- and oligosaccharide functionalization

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Immobilized Enzyme Monolithic Platform for Tailored Poly- and Oligosaccharide Functionalization

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The exploitation of functional poly- and oligosaccharides has attracted extensive interest due to their diverse applications in cosmetics, health, nutraceuticals, and the food industry. Over the past decade, immobilized enzymatic catalysis, as a green chemistry technique, has been employed to modify polysaccharide molecules and generate novel bioactive oligosaccharides. In this study, an immobilized enzyme reactor (IMER) system comprising two primary enzymatic compartments was constructed. The first compartment, consisting of a monolithic Convective Interaction Media® (CIM®) carboxy imidazole (CDI) disk with immobilized laccases (EC 1.10.3.2) from *Trametes versicolor*, was designed to introduce phenol groups into polysaccharides. Dextran T40, selected as a model polysaccharide, was used to evaluate the phenolization process. The second compartment was designed to break down polysaccharides, leading to the production of oligosaccharides. A CIM® CDI disk with immobilized glucuronan lyases (EC 4.2.2.14) from *Rhizobium rosettiformans* was employed to degrade glucuronan. In both compartments, the kinetic parameters of free and immobilized enzymes were quantified, including the maximum reaction rate (Vmax) and the Michaelis constant (Km). To optimize enzymatic catalysis, design of experiments (DOE) and response surface methodology (RSM) were applied to investigate the effects of key operating parameters, i.e., substrate concentration, flow rate, and reaction time. The stability of the immobilized enzyme reactor was also monitored to assess its lifespan. Finally, we aim to integrate these two compartments with a membrane filtration system to develop a multistep enzymatic reactor for the controlled processing of poly- and oligosaccharides.

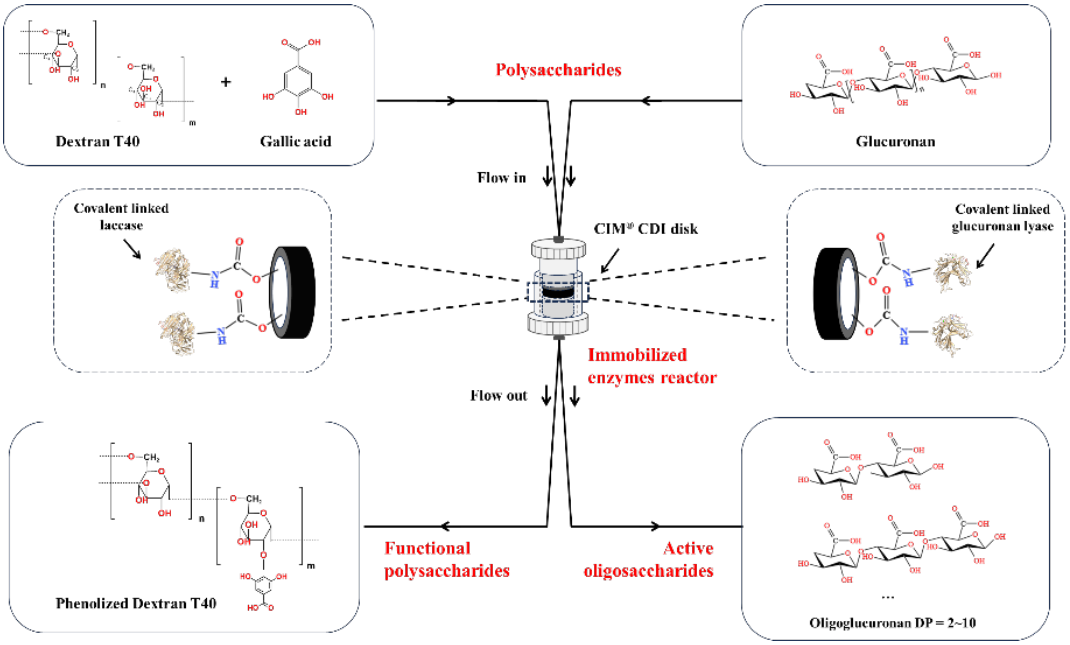

Figure 1. Schematic diagram of CIM® CDI monolithic reactors immobilized with laccases or glucuronan lyases for producing functional polysaccharides or active oligosaccharides, respectively.

O30.2 - Passerini Modified Carboxymethyl Cellulose: Towards Dually Crosslinked Hydrogels

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Passerini modified Carboxymethyl cellulose:

towards dually crosslinked hydrogelS

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With aim of imparting new properties to polysaccharides and broadening their application range, their chemical modification is a promising strategy. The emergence of efficient and sustainable functionalization pathways allowing tailor-made chemical modifications is highly desired and constitutes a major challenge. In this context, multicomponent reactions (MCRs) are of particular interest and fulfill some criteria of green chemistry [1]. MCRs are versatile reactions, with high atom efficiency, for which three or more reactants simultaneously react to yield a single final structure, incorporating the majority of atoms of the raw precursors. Among MCRs, the Passerini three-component reaction (P-3CR) is especially suitable for polysaccharide modification, as it involves a carboxylic acid, a carbonyl compound (typically an aldehyde), and an isocyanide to form an α-acyloxycarboxamide linkage, conducted in an aqueous medium in catalyst and coupling reagent-free conditions. In recent years, IMP laboratory has been working on the functionalization of polysaccharides, including carboxymethyl cellulose (CMC) [2], by P-3CR to develop novel families of dually functionalized derivatives, that have been notably utilized to design thin films [3], chemical [4] and physical hydrogels. The present work contributes to this research and describes the synthesis of even more sophisticated CMC derivatives through the Passerini reaction. These CMC derivatives are functionalized both by reactive moieties (methacrylate and thiol-ene approaches) and by thermosensitive oligomers exhibiting LCST behavior in water, such as poly(alkylene oxide) copolymers (PEO-*co*-PPO). The ultimate goal is to generate new chemically crosslinked CMC hydrogels (*via* UV-vis. irradiation) that are also temperature-sensitive (*Figure 1*). To this end, we present various Passerini modifications that we have implemented. Experimental parameters were adjusted to select the most efficient approach and to optimize grafting yields. The most promising derivatives, especially those bearing norbornene groups and LCST segments, were used to prepare chemically crosslinked hydrogels. The physico-chemical properties of these hydrogels (e.g., rheology, swelling behavior...) were characterized in relation to the crosslinking conditions. Additionally, the temperature response was examined both before and after chemical crosslinking. The modular character of the Passerini reaction thus paves the way of designing innovative and tailor-made polysaccharide-based derivatives and materials.

CMC

LCST oligomer

UV-reactive function

(crosslinker)

photoinitiator

hν (395 nm)

RT

H_2O

chemical hydrogel

$T > T_{LCST}$

$T < T_{LCST}$

+ **physical interactions**:

T° triggering hydrophobic associations of LCST substituents beyond a critical temperature

Figure 1: Strategy for designing dually crosslinked hydrogels

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O30.3 - CLICK CHEMISTRY-BASED SYNTHESIS AND ANTIBACTERIAL PROPERTIES OF CRAMP-18 PEPTIDE CONJUGATED CHITOSAN

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Click Chemistry-Based Synthesis and Antibacterial Properties of CRAMP-18 peptide Conjugated Chitosan

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Antimicrobial peptides (AMPs), vital components of organisms' innate immune systems, combat diverse microbial infections, including bacteria, fungi, viruses, and parasites, by disrupting microbial membranes and essential processes [1,2]. AMPs offer a promising alternative to traditional antibiotics due to their broad-spectrum activity [3]. CRAMP (Cathelicidin-Related Antimicrobial Peptide), found in mice immune cells, is a specific AMP [4]. Chitosan, derived from chitin in crustacean exoskeletons and fungal cell walls, is a versatile natural polysaccharide with wide-ranging applications in pharmaceuticals, food, cosmetics, agriculture, and wastewater treatments.

Our approach utilizes azide transfer reactions and copper-catalyzed azide-alkyne cycloadditions (CuAAC) to attach antimicrobial peptides (CRAMP-18) to chitosan and hydroxypropyl chitosan (HPC).) [5]. Chitosan azide and HPC-azide were prepared with controlled azidation using imidazole sulfonyl azide, followed by a click reaction to obtain the desired product. These derivatives were characterized by IR and NMR spectroscopy. The antibacterial activity of the chitosan-peptide conjugates was evaluated against four bacterial species *S. aureus, E. faecalis, E. coli,* and *P. aeruginosa.*

The successful grafting of pentynoyl-CRAMP18 onto chitosan and HPC was achieved through the CuAAC reaction. This chemical process facilitated robust bonding between the peptide and the polymers. Proton NMR spectroscopy confirmed the conversion of azide groups to 1,2,3-triazole linkages, enabling assessment of the degree of substitution (DS) in chitosan-peptide conjugates. DS values for chitosan-CRAMP18 (**1**) and HPC-CRAMP18 (**2**) were 0.2 and 0.13, respectively, indicating successful peptide incorporation onto both polymers. Notably, chitosan peptide conjugates **1** and **2** displayed significant efficacy against Gram-negative bacteria, especially *E. coli*.

We successfully conjugated the CRAMP-18 peptide to chitosan using the CuAAC reaction. This study demonstrates that chitosan-peptide conjugates have potential antibacterial properties.

Acknowledgement:

The research work was funded by the Icelandic Research Fund (Rannis Grant No. 1709-0210).

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O30.4 - REGIOSELECTIVELY SULFATED DERIVATIVES OF ALGINATES AND BETA-GLUCANS

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

REGIOSELECTIVELY SULFATED DERIVATIVES OF

ALGINATES AND β-GLUCANS

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Sulfated polysaccharides are negatively charged biomacromolecules widely distributed in Nature. Among them, the most important ones are the sulfated glycosaminoglycans (GAGs), as they play key roles in a plethora of physiological and pathological processes – especially in animals, including humans – such as immunity, angiogenesis, cancer, infectious diseases *etc* [1]. GAGs are able to encode a variety of biological information through their sulfation pattern, *i.e.* the distribution of the sulfate groups along their polysaccharide backbone [2].

Pharmaceutical- and nutraceutical-grade marketed sulfated GAGs are commonly extracted from animal tissues, even if this raises some problems: ethical and ecological concerns, the risk of contamination with animal proteins as well as the difficulty in controlling the distribution of sulfate groups along the polysaccharides, as the latter depends not only on animal species and tissue but also on the physiopathological conditions – aging, inflammation, tumor formation *etc.* – of the single animal. For these reasons, in the last years much effort has been put into the engineering of artificial sulfated polysaccharides (ASPs) as GAG-like species, through chemical, enzymatic or chemo-enzymatic sulfation of natural, unsulfated polysaccharides [3]. ASPs are often obtained by random sulfation reactions, that are not able to control the regioselectivity of the installed sulfate groups within the repeating unit of the polysaccharide [4,5]. Since the general goal of ASPs production is to let them act as analogues of sulfated GAGs, it is mandatory to develop methods for the control of regioselectivity in the derivatization of the native polysaccharides.

In this communication, a thorough investigation of several chemical strategies, based on either direct or multi-step approaches, towards the obtainment of regioselectively sulfated derivatives of alginates and β-glucans is presented [6,7]. These families of polysaccharides have been selected for the study because they are commercially available from non-animal sources and show interesting properties, biological activities and applications not only in their native, unsulfated forms, but also as randomly sulfated derivatives [8,9]. Therefore, the access to a comprehensive set of sulfated alginate and β-glucan derivatives differentiated for their sulfation pattern could be a key tool for investigating in details their structure-activity relationships as sulfated GAG mimics in several biological events.

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O30.5 - COVALENT CROSSLINKING OF ALGINATE BY NATIVE CHEMICAL LIGATION

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

COVALENT CROSSLINKING OF ALGINATE BY

NATIVE CHEMICAL LIGATION (NCL)

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Polysaccharides are often used as polymer precursors for biomedical hydrogel design due to their high natural abundance, renewable character, hydrophilicity, biodegradability and biocompatibility. However, their naturally predefined composition limits their compatibility with many crosslinking chemistries essential for chemical and mechanical stability of produced hydrogels. The resulting need for chemical modification of biopolymers with reactive moieties often hampers their initially favored biocompatibility and motivates a high demand for water-friendly, chemo-selective and non-toxic crosslinking strategies for synthesis of hydrogels with suitable mechanical properties without sacrificing biocompatibility and bioactivity. [1,2]

Native chemical ligation (NCL), a method widely used in protein synthesis, enables covalent bond formation under aqueous conditions without any additional reagents or catalysts, yielding native peptide bonds between C-terminal peptide thioesters and N-terminal peptide L-cysteine residues.[3] In our study, sodium alginate (Alg, I) was functionalized with amino acid-based thioesters (AA-SR) and crosslinked with bifunctional L-cysteine linker molecules. The resulting hydrogels were formed under ambient conditions in an aqueous, pH-neutral medium, offering an innovative approach for covalent crosslinking of alginate compatible with the physiological environment. This method opens up new possibilities for therapeutic hydrogel systems with potential applications in drug delivery, regenerative medicine and tissue engineering.

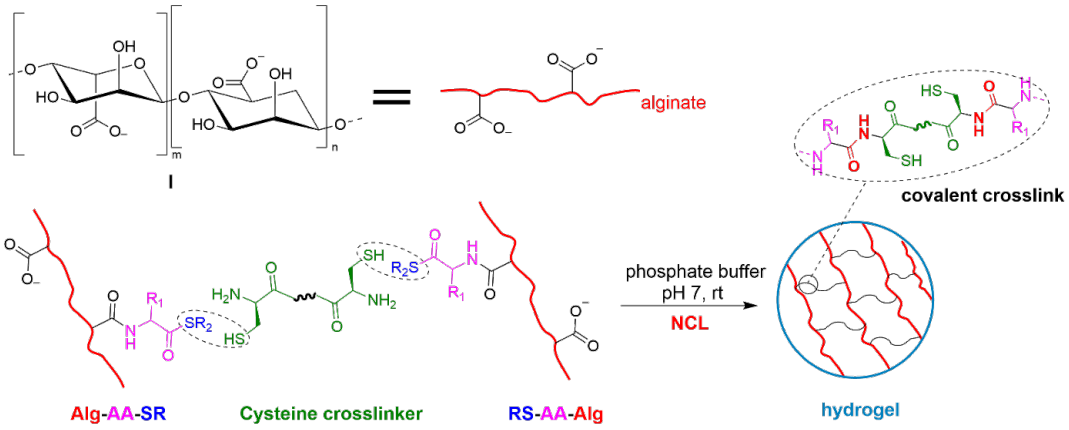

Figure 1. General strategy for crosslinking of alginate by NCL.

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O30.6 - PROTEIN BINDING QUANTIFICATION AND ORIENTATION ON CHITIN/CHITOSAN SURFACE INTERACTION PLATFORM: THE ROLE OF CHITIN-BINDING DOMAINS

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

PRotein binding quantification and orientation on chitin/Chitosan Surface Interaction Platform: the role of chitin-binding domains

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[b] Microbiologie, Adaptation et Pathogénie (MAP), Universite Claude Bernard Lyon 1, INSA Lyon, INRAE, CNRS UMR 5240, France

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Surface-protein interactions play key roles in various fields, including biomedicine, nanotechnology, and the biology of plant-insect interactions. In the latter case, understanding how proteins – both with and without chitin-binding domains (CBD) – interact with chitin or chitosan (CS) is essential and may pave the way for innovative crop pest control strategies. Notably, proteins containing CBD, which are found in the cuticle of arthropods, also exist in plants, where they play a crucial role in detecting insect aggressions. [1]

To investigate the surface interactions of proteins with CS, we have developed a platform which enables the study of the interactions of proteins with or without CBD and which discriminates their behaviors. The platform consists of CS thin films of varying degrees of acetylation ($0.5\% \leq DA \leq 76\%$) covalently grafted by surface silanization, spin-coating and water-temperature treatment. [2,3] The obtained films were characterized by infrared spectroscopy, contact angle, atomic force microscopy, X-ray scattering. The affinity of proteins (with CBD: wheat germ agglutinin, WGA; without CBD: immunoglobulin G, IGG) for CS-coated surfaces was assessed by fluorescence microscopy, which allows the quantification of the proteins bound to the surface. [4] The specific affinity of WGA was demonstrated in comparison with CBD-free proteins: affinity is stronger at higher DAs, suggesting that the acetylation pattern plays a role in specific binding to CBD. The specificity of CBD interactions with CS and the impact of DA were also demonstrated by dynamic measurements using quartz crystal microbalance with dissipation measurement (QCM-D). [5] The mass of WGA adsorbed on CS is significantly higher than that of IGG; it is also almost twice as high at high DA (> 50%) than at low DA (< 40%), indicating a more specific interaction with CS close to chitin.

The developed platform demonstrates promising results in screening protein-CS interactions. To our

knowledge, it is the first method capable of distinguishing between the interactions of proteins with and without CBD with CS using straightforward, direct quantification techniques. Additionally, this platform could be used for other chitin-binding proteins or extended to study polysaccharide-protein interactions more broadly.

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Parallel session 31 - Materials & Engineering

2025-08-27
15:50 - 17:50
Parallel session 31 - Materials & Engineering

O31.1 - Polysaccharide monolayers displaying low ice adhesion properties

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

POLYSACCHARIDE MONOLAYERS DISPLAYING LOW ICE ADHESION PROPERTIES

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The formation of ice on solid surfaces can cause many issues and hazards. Active strategies for ice removal, requiring energy input or chemicals, can be complemented by passive strategies, based on icephobic materials. Superhydrophobic materials, which allow the removal of water before freezing occurs and have long been considered as the most promising icephobic candidates, present a few issues, and lose their properties in high relative humidity conditions. Interestingly, on the opposite side of the wettability spectrum, hydrophilicity can also be exploited for the design of icephobic surfaces. In this field, polysaccharides represent an interesting option, due to their hydrophilicity, biodegradability and non-toxicity. Studies have shown that polysaccharides can strongly bound water molecules and avoid the freezing of the so-called “bound water” at temperatures below 0 °C. This can lead to the formation of a layer of liquid water on which ice can slide and be easily removed. [1,2]

In this context, two linear polysaccharides, namely chitosan and hyaluronic acid, were used to produce polysaccharide monolayers with a thickness of approximately 10 nm. Glass was chosen as substrate, while a commercial adhesion promoter, AziGrip4^{TM} [3], was used to link the polysaccharides to the substrate. Hyaluronic acid monolayers showed very promising results, with a 5-fold decrease in ice adhesion strength when compared to bare glass (Figure 1). In addition, sliding of ice on these materials was observed, suggesting the presence of a quasi-liquid water layer. The complete transparency that characterizes these materials makes them potentially suitable for solar panels and windscreens design.

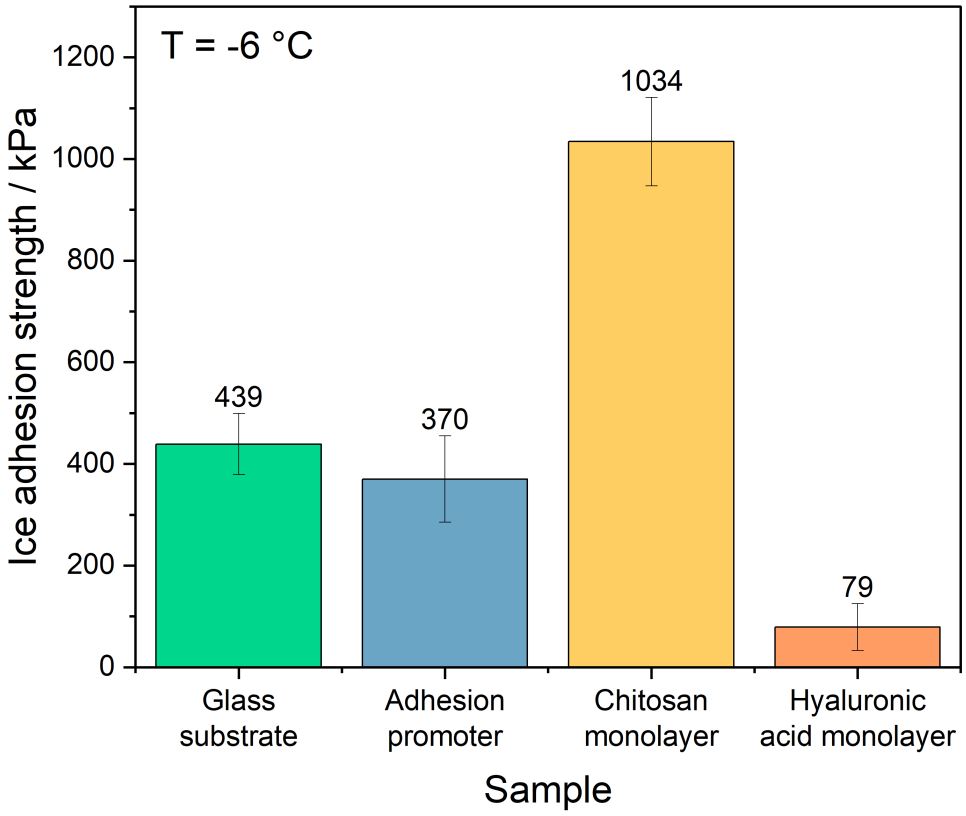

Figure 1. Ice adhesion strength values on glass, glass covered by the adhesion promoter, chitosan monolayer and hyaluronic acid monolayer.

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O31.2 - ALL-CELLULOSE COMPOSITES AND PHASE CHANGE MATERIALS: CHARACTERIZATIONS FROM THE EMULSION STATE TO THE END-PRODUCT

Energy Applications
Materials & Engineering

All-cellulose composites and Phase change materials: characterizations from THE emulsion sTATE to THE end-Product

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In a context of global warming, energy should be used wisely. The development of efficient insulation materials has been a hot topic in research for a long time.[1] Cellulose is a material of choice for sustainable insulation.[2] It is abundant, biobased, biodegradable and already used as is for this purpose. It also has good mechanical properties making it an ideal building material. In the last decades, phase change materials (PCM) raised interest as passive heat storage.[3,4] PCM either store or release heat when the material undergoes fusion or crystallisation. Because of the transition from a solid to a liquid state, practical uses of PCM often involve an encapsulation step in a solid substrate.

Several attempts of cellulose-PCM composites have been made.[5–10] However, the complete encapsulation of PCM has proven to be difficult and cellulose is rarely used “as is”. Partial dissolution of cellulose at high concentration can be achieved using some ionic liquids (ILs). These cellulose solutions can present a variety of physical states from interpenetrating coils in a seemingly ideal solution state, to liquid crystals or cellulose suspensions forming anisotropic liquids. The coexistence of those states in highly concentrated cellulose solutions has led to the manufacturing of “all-cellulose composites” where an undissolved or highly oriented fraction can reinforce a fully dissolved and essentially isotropic matrix.

In this work, a new all-cellulose/PCM composite is studied. The heterogeneity of the cellulose solutions was taken advantage of to successfully microencapsulate the PCM. Each step of the process was extensively characterized by multiple techniques to follow the evolution of the properties and the microstructure. The properties of cellulose solutions in tetrabutylphosphonium hydroxide**,** an easily washable and recyclable IL, were studied by rheology, SAXS and NMR from dilute to concentrated regimes. Then, the transfer of their properties during the gelation process was characterized by SAXS, liquid AFM and μCT on the hydrogels made from them. The formulation of the end material was investigated for load of an organic PCM between 25 wt.% and 75 wt.%, with various polymerization degrees and concentrations of cellulose. The influence of the composition of the cellulose solution in the encapsulation of the PCM by emulsification was monitored by POM and SEM. Finally, the microstructural and thermal properties of the all-cellulose/PCM were characterised by hyperspectral microscopy, temperature-controlled IR spectroscopy and DSC.

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O31.3 - PARAFFIN AS A PHASE CHANGE MATERIAL IN AN ALL CELLULOSIC COMPOSITE STUDIED IN PFG-NMR AND COUPLED DSC-IR

Energy Applications
Materials & Engineering

Paraffin as a phase change material in an all cellulosic composite studied in PFG-NMR and coupled DSC-IR

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Cellulose is a bio-sourced material used in various domains, such as textiles and thermal insulation, when combined with a phase change material (PCM). An essential step in the elaboration of such materials is the dissolution of cellulose, which is known to be difficult to achieve in common organic solvents due to its strong intra- and intermolecular hydrogen bonds. Many newer and greener solvents, such as some ionic liquids have been reported to dissolve cellulose at various weight percentages[1,2]. Nuclear magnetic resonance (NMR) is a powerful tool used to gather a variety of information on the local structure of the material, as well as on dynamics and molecular diffusion. It can be successfully, though infrequently, applied to investigate the efficacy of a solvent in dissolving cellulose [3–5]

In this work, we will first report dissolution study of cellulose in 1H and 13C Pulse field gradient NMR. Essential characteristics of the dissolution step were obtained, through the monitoring of diffusion coefficient of the different species, at various weighted percentage of dissolved cellulose. Firstly, different diffusion regimes of the species in solution were observed and linked to the number of bound solvent cations to the dissolved cellulose, thus permitting the determination of the hydrodynamic radii of the solutes. Secondly, critical concentrations of dissolution systems were deducted, which was essential to better understand the dissolution step and allows us to form an all cellulosic composite. In a second instance, we will present a thermal and structural study on a paraffin as a phase change material in the all cellulosic composite, through a coupled DSC-FTIR study. We specifically determined simultaneously the structural/spectroscopic evolution of the materials undergoing a phase changes while determining heat flows in repeated heating/cooling cycles, demonstrating the superiority of this coupling.

In conclusion the overall study of a PCM in a composite from the elaboration of the material to the understanding of the structural changes and thermal performances, PFG-NMR, and a system of a coupled DSC-IR give an indepth and complete study of the material through the different steps and heat/cool cycles.

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O31.4 - Butanediol from forest based residual streams

Materials & Engineering

Butanediol from forest based residual streams

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The chemical industry's dependence on fossil-derived raw materials accounts for approximately 5% of global CO_2 emissions [1]. Meanwhile, the forest industry generates large volumes of low-value residual by-products, such as sawdust and fiber rejects, which are mainly used for energy production through combustion [2].

Butanediol (BDO) is a high-value platform chemical with diverse industrial applications [3]. In response to the growing demand for sustainable chemical production, this study investigates the microbial production of 2,3-butanediol (2,3-BDO) from forestry-based residual streams as an alternative to traditional fossil-based production methods.
In this project, sawdust was pretreated and enzymatically hydrolyzed using Sekab's CelluAPP® technology, while fiber reject from Metsä Board Sverige was directly hydrolyzed into sugars. This resulted in 128.3 g/L of sugars from sawdust and 113.7 g/L from the fiber reject at lab scale. Sawdust was also processed at the Biorefinery Demo Plant on a larger scale, achieving a sugar concentration of 451.2 g/L.

For 2,3-BDO production, engineered *Saccharomyces cerevisiae* strain HGS37 [4] capable of producing >100 g/L of 2,3-BDO from synthetic glucose with > 48% conversion yield (theoretical ~50%) were tested on hydrolysate of both feedstocks. In small scale experiments, higher yield (C6 sugars to 2,3-BDO) on both fiber reject hydrolysate (49.1% yield from 67.4 g/L C6 sugars) and saw dust hydrolysate (49.5% yield from 84.9 g/L C6 sugars) were achieved. Further scaling up the process to bioreactor improved sugar consumption rate and resulted in increase in 2,3-BDO maximum specific production rates to 3.2 g/L/h for fiber reject and 2.2 g/L/h for sawdust medium. This study also involves downstream processing, where microbial cells are first removed, and the 2,3 -BDO is extracted from the fermentation broth through liquid-liquid extraction, where different solvents were evaluated.
This study demonstrates the efficient conversion of forestry-based residual streams into high-concentration sugars, which were successfully fermented and optimized for high-titer 2,3-BDO production. Various solvents for liquid-liquid extraction were tested, and the optimization of the downstream process for higher purity 2,3-BDO will be emphasized in the presentation. This research contributes to the development of more sustainable chemical production by promoting the use of forest biomass as a feedstock for biorefinery applications and fostering long-term collaborations

between the forestry, biorefinery, and chemical industries.

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O31.5 - ENERGY CANE – SHREDDING AS A PERFECT PRE-TREATMENT TO MAXIMIZE BIOMETHANE PRODUCTION

Energy Applications
Materials & Engineering

ENERGY CANE – SHREDDING as A PERFECT pre-treatment to MAXIMIZE BIOMETHANE PRODUCTION

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The transition from fossil fuels to more environmentally friendly processes is a key area of research, with biogas considered a powerful option due to its potential for reducing greenhouse gas emissions. Anaerobic digestion (AD) is a widely used process capable of converting diverse biomass sources into biogas. This study evaluates the Biochemical Methane Potential (BMP) of energy cane (EC) at different maturity stages and varying shredding levels. [1]. Sugarcane breeding programs developed the energy cane and the pioneer conceptualization of the use of energy cane in sugarcane mills was in Puerto Rico. It was tailored as a plant to be harvested integrally, using all the lignocellulosic biomass for energy purposes i.e. stalks, leaves and straw, and bagasse[2].

We analyzed samples of EC dried at 8 months of maturity (EC08dry) and 11 months of maturity (EC08fresh and EC11fresh) previously shredded once, twice, or three times. Positive (microcrystalline cellulose - MC) and negative (anaerobic inoculants INIrac and INAmBev) controls were included. Biogas production followed the German VDI 4630/2006 methodology, while characterization tests adhered to ALPHA (1999) protocols. [1]

Methane concentrations ranged between 50% and 70% across all conditions. The BMP values obtained varied from 273 mL CH4/g VS for EC_{08dry}, and 346 mL CH4/g VS for $EC_{08fresh}$ and 129 mL CH4/g VS for $EC_{11fresh}$. Among all tested samples, $_{EC08fresh}$ exhibited the highest BMP, accumulated methane volume, and biodegradability. [1]

These results indicate that EC is an attractive feedstock for biomethane production, particularly due to its high vegetal yield (usually 40% larger than conventional sugarcane, expressed in ton/hectare/ year) and optimal biomethane conversion. Shredding was found to be an effective pre-treatment method, although increasing the number of shredding steps did not yield significant differences. Furthermore, the findings suggest that EC recalcitrance increases with maturity, leading to a decrease in methane production. [1]

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O31.6 - FROM WOOD TO FIBRILS: A NEW ROLE FOR IONIC LIQUIDS

Textile, Pulp, Paper & Packaging
Materials & Engineering

From wood to fibrils: A New role for Ionic Liquids

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Modernisation of the forest industries requires adaptation of sustainable practises during the development and production of common goods. This can be achieved by efficient utilization of the forest resources, reduction of the CO_2 emissions and water consumption [1]. One way to target the efficient utilization of the renewable resources and to reduce the CO_2 emissions, would be by improving or developing new pulping methods. Here in, we present a novel concept for direct fibrillation of wood utilizing ionic liquids, thus enabling for efficient utilization of the forest resources [2].

Some ionic liquids are efficient media for the dissolution of cellulose, one of the main components of wood. However, while the direct dissolution of solid wood is more complex, selective dissolution of some component(s) is an attractive opportunity. We have found that some ionic liquids are able to dissolve some of the minor components of the wood matrix selectively, thus leading to direct wood fibrillation. During this process the solid wood is turned into fibrous material ready to be utilized for further product development (figure 1, down).

Figure 1. Blunt tool approach (up) vs. precise tool approach (down) for wood pulping/fibrillation

[1] Main goals for Emission Free Pulping program

[2] This research is part of the Emission Free Pulping program

Parallel session 32 - Materials & Engineering

2025-08-27
15:50 - 17:30
Parallel session 32 - Materials & Engineering

O32.1 - DOUBLE-NETWORK HYDROGELS WITH ENHANCED MECHANICAL PROPERTIES, ADHESION ABILITY AND IONIC CONDUCTIVITY FOR WEARABLE STRAIN SENSORS

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Double-network hydrogels with enhanced mechanical properties, adhesion ability and ionic conductivity for wearable strain sensors

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Ionic conductive hydrogels have recently attracted tremendous attention in flexible wearable strain sensors. However, achieving a combination of good mechanical properties, strong adhesion to various material surfaces, and remarkable ionic conductivity in a single ionic conductive hydrogel remains a challenge. Herein, new poly(acrylamide-co-sulfobetaine methacrylate)/chitosan/phytic acid (ASCP) ionic conductive hydrogels with double networks were prepared through free radical polymerization (Fig. 1) [1]. The versatile functional groups from chitosan and phytic acid gave the hydrogels universal adhesion capabilities with a maximum adhesion strength of 18.7 kPa to paper. The obtained ASCP conductive hydrogels exhibited a large elongation of 675 % and a moderate tensile strength 52.8 kPa due to the synergy of chemical cross-linking and physical interactions. Phytic acid as the conductive component conferred the hydrogels with excellent ionic conductivity of 10.3 S m^{-1}. Moreover, the incorporation of chitosan and phytic acid imparted the hydrogels with enhanced anti-drying capability, as evidenced by a residual mass ratio of 58.3 % after 10 days, and exhibited favorable anti-swelling behavior, with an equilibrium swelling ratio of 115 % in water after 4 days. The described ionic conductive hydrogels were assembled into wearable strain sensors to detect various human joint movements. This work offers a straightforward strategy to design multifunctional conductive hydrogels which envision prospective applications in wearable sensors and other flexible electronic devices.

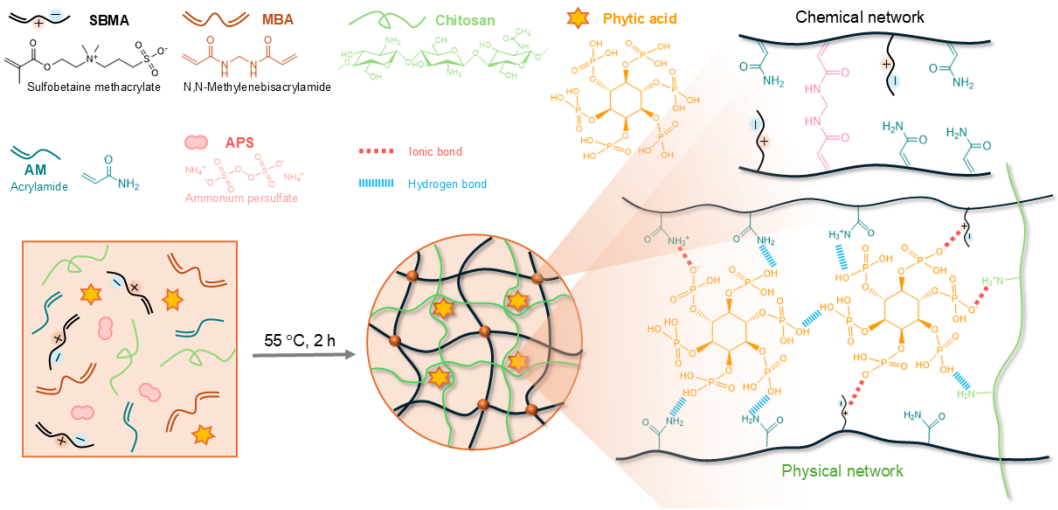

Fig. 1. Schematic illustration of the hydrogel preparation.

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O32.2 - INJECTABLE HYALURONAN-BASED THERMORESPONSIVE HYDROGELS WITH A TUNABLE TRANSITION TEMPERATURE

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

INJECTABLE Hyaluronan-based THERMORESPONSIVE hydrogels with a tunable transition temperature

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Hydrogels are soft materials with a high water content and mechanical properties close to those of living tissues. They are thus tremendously scrutinized as potential biomaterials for biomedical applications [1]. Enhancing their biocompatibility can be achieved by manufacturing them from biopolymers, such as polysaccharides or polypeptides. In particular, hyaluronan (HA) stands out, as it is a glycosaminoglycan produced within the human body, where it is involved in articulation lubrication and cell signalling [2]. However, HA requires to be cross-linked in order to be turned into a hydrogel.

Although weaker than chemical crosslinks (covalent bonds), physical crosslinks (weak bonds) will result in reversible structures, which allow more flexibility for some applications, such as injectable materials. For this specific application, the material should indeed transition from a solution state (sol) prior to the injection to a gel state after the injection, which can be achieved with carefully selected stimuli-responsive physical crosslinks.

The strategy presented here consisted in grafting thermoresponsive copolymers of 2-isopropyl-2-oxazoline and 2-*n*-butyl-2-oxazoline (P(*i*PrOx-*co*-*n*BuOx)), displaying a LCST (*'Lower Critical Solution Temperature'*) behaviour, to a HA backbone, in order to obtain comb copolymers able to undergo a sol to gel transition by raising the temperature (Figure 1a) [3]. The thermal transition could notably be tuned by adjusting the composition of the grafts (Figure 1b) [3]. The injectability of this system was evaluated through rheological measurements [4].

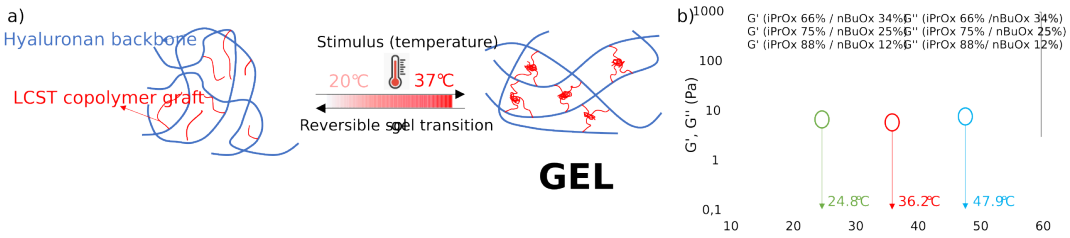

Figure 1. a) Depiction of the concept of a thermoresponsive hyaluronan-based hydrogel. b) Thermal transition of several HA-*g*-P(*i*PrOx-*co*-*n*BuOx) aqueous solutions (15 $g.L^{-1}$, PBS) with various side-chain compositions (M_n(HA): 990 000 $g.mol^{-1}$; DP_{POx}: 27; DS_{POx} ~ 10%)

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We would like to thank the Normandy region and the ERDF for financial support (NeuroOncoChimie project)

O32.3 - DOPING FERULOYLATED ARABINOXYLAN COVALENT HYDROGELS WITH CELLULOSE NANOCRYSTALS

Nanostructured Materials
Materials & Engineering

Doping feruloylated arabinoxylan covalent hydrogels with cellulose nanocrystals

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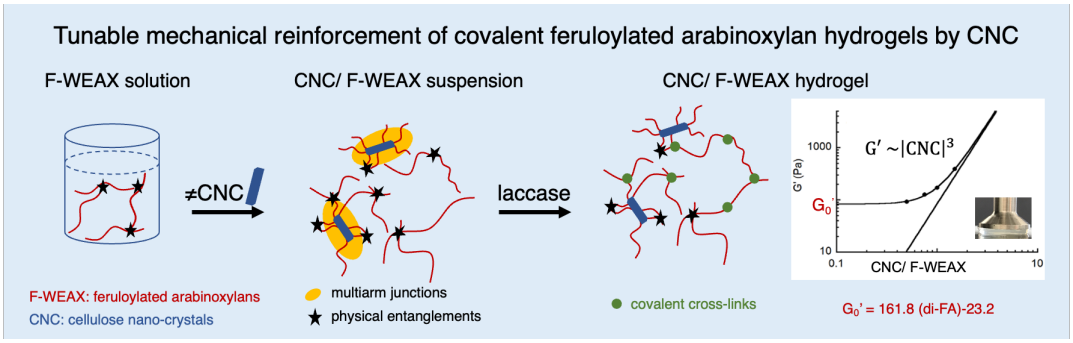
Although quite abundant, feruloylated arabinoxylans are poorly valued today. They are water soluble and lead to covalent hydrogels simply by oxidation of the ferulic moieties [1]. These macroporous hydrogels, with mesh sizes ranging from 40 to 400 nm, are stable whatever the pH and ionic strength, and can absorb up to 150 grams of water per gram of polymer. While their structure and swelling capacity make them good candidates as encapsulation matrices [2], their mechanical strength (elastic modulus of the order of 100 Pa) needs to be improved to extend their use as materials.

The study investigates the enhancement of viscoelastic properties in feruloylated arabinoxylan (F-WEAX) hydrogels by incorporating cellulose nanocrystals (CNC). F-WEAX, a cereal cell wall polysaccharide, was crosslinked using laccase in the presence of CNC, with CNC/F-WEAX weight ratios ranging from 0 to 1.5. The addition of CNC significantly increased gel stiffness, with the elastic modulus scaling as $[CNC]^3$. CNC also influenced relaxation behavior, enhancing the loss factor at low frequencies.

Quartz crystal microbalance with dissipation (QCM-D) measurements showed that F-WEAX adsorbed irreversibly onto CNC, similar to non-feruloylated arabinoxylans. In the presence of CNC, laccase action led to twice as many elastically active oxidation products, namely dimer and trimer forms of ferulic acid (FA). Consequently, the swelling capacity of F-WEAX-CNC gels decreased but less than expected from the increase in shear modulus. This synergistic enhancement of elasticity while maintaining swelling capacity is attributed to the formation of high-functionality junctions through the irreversible adsorption of F-WEAX onto CNC.

The study concludes that the introduction of CNC prior to F-WEAX gelation significantly improves elastic properties more effectively than increasing F-WEAX concentration alone. This is due to the high affinity of F-WEAX for CNC, increased cross-link density, and the formation of multi-armed junctions. The findings highlight the potential of CNC in enhancing the mechanical properties of biopolymer hydrogels, which can be achieved through simple mixing.



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O32.4 - Electrostatic Complexations of Carboxylated Cellulose Nanofibrils and Quaternized Chitosan for Antimicrobial Coatings

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Electrostatic Complexations of Carboxylated Cellulose Nanofibrils and Quaternized Chitosan for Antimicrobial Coatings

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Hospital materials are exposed to microbial contamination, especially when in direct contact with human fluids. For example, endotracheal tubes (ETTs) generate a biofilm that can lead to serious health complications, posing serious risks for critically ill patients. ETTs are generally made from polyvinyl chloride (PVC). Current antimicrobial strategies often rely on silver coatings or antibiotic release, which raises concerns about cytotoxicity, resistance, or coating instability. Here, we present a sustainable strategy to fabricate antimicrobial and biocompatible coatings for ETTs using polysaccharides. A major challenge lies in achieving strong adhesion between the polysaccharides and the hydrophobic polymer substrate. We studied how electrostatic complexation of oppositely charged polysaccharides such as carboxylated cellulose nanofibrils (C-CNFs) and Trimethyl chitosan (TMC) could produce such coatings. The C-CNFs were extracted from rose stem residues using a green one-pot process and exhibited high purity with small diameter ~3.2 nm and high aspect ratio ~784. TMC, a cationic chitosan derivative, was synthesized through methylation of chitosan, introducing quaternary ammonium groups. In aqueous environments, C-CNFs and TMC spontaneously self-assemble into electrostatically bonded nanofiber networks. This self-assembly approach may enable multilayer coating strategies, where the negatively charged surface of PVC facilitates initial TMC adsorption, followed by C-CNF as an intermediate binding layer, and a final outer TMC layer to impart antimicrobial functionality. We aim to study how surface charge, coating sequence, and potential swelling behavior influence coating adhesion and stability. The resulting C-CNF/TMC coating is expected to provide conformal surface coverage, strong interfacial binding without toxic crosslinkers, and exhibit excellent antibacterial, antifouling, biocompatible, and biodegradable properties. This green, scalable approach holds promise for next-generation ETT coatings that can reduce mucus adhesion, inhibit biofilm formation, and prevent ventilator-associated pneumonia (VAP) in clinical settings.

Keywords: Cellulose nanofibrils; Trimethyl chitosan; Self-assembly; Antimicrobial coating; Endotracheal tube; Green chemistry; Ventilator-associated pneumonia.

O32.5 - Tailoring amphiphilic hemicellulose derivatives in suberin dispersions

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Tailoring amphiphilic hemicellulose derivatives in suberin dispersions

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The growing environmental impact of fossil-based resources highlights the need for sustainable, high-performance packaging materials. Therefore, renewable, biomass-based alternatives offer significant potential to contribute to a circular bioeconomy. In this work, we aim to utilize overlooked forest industry byproducts and explore their potential in developing value-added applications for packaging and coatings.

Our objective is to formulate a sustainable aqueous dispersion coating, stabilized by a bio-based surfactant derived from hot-water-extracted wood hemicelluloses. Specifically, this study focuses on hemicelluloses and biopolyesters, materials commonly overlooked as side streams in conventional forest product processing. In particular, we investigate suberin, extracted from cork and bark, known for its inherent hydrophobic properties that could improve barrier performance in fiber-based packaging [1]. However, due to its hydrophobicity, dispersing suberin in water requires a dispersing agent. To address this, we developed hemicellulose-based surfactants from galactoglucomannans (GGM), the primary hemicellulose in softwood, functionalized via esterification with naturally occurring fatty acids to create amphiphilic derivatives with tuneable properties. Briefly, GGM was modified with fatty acids of varying chain lengths and degrees of substitution to investigate their influence on performance. Additionally, three different molar masses were used to evaluate the impact of molecular weight on dispersing ability. Suberin dispersion stability was assessed using rheology, turbidity measurements, and microscopy analysis. This study supports the development of stable aqueous suberin dispersions and contributes to advancing bio-based coating formulations with enhanced barrier properties for sustainable packaging applications.

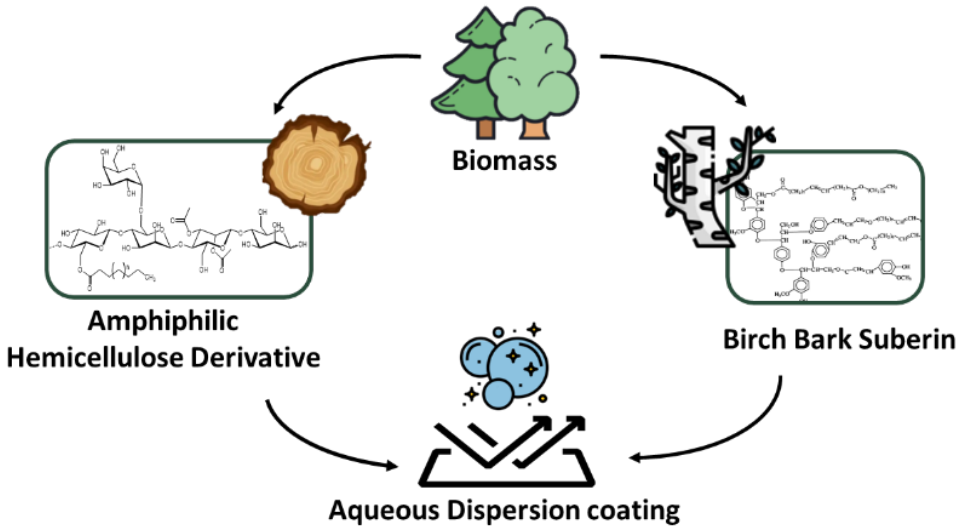

Figure 1. From biomass to biobased aqueous dispersion coating

[1.] J. Heinämäki, A. Halenius, M. Paavo, S. Alakurtti, P. Pitkänen, M. Pirttimaa, U. Paaver, K. Kirsimäe, K. Kogermann, J. Yliruusi, Int J Pharm 2015, 489, 91.

Parallel session 33 - Materials & Engineering

2025-08-28
11:30 - 12:30
Parallel session 33 - Materials & Engineering

O33.1 - VISUALIZING THE CHEMISTRY OF LIGNOCELLULOSIC MATERIALS ACROSS ALL HIERARCHICAL STRUCTURES

Compositional Analysis
Chemistry, Biology & Physics

Visualizing the chemistry of lignocellulosic materials across all hierarchical structures

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[2] Dept. of Neuroscience, Karolinska Institutet, Sweden

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Detailed understanding of the spatial-chemical composition of lignocellulosic networks in plant tissue is needed to ensure optimal utilization. Using the fluorescent tracer molecule Carbotrace 680, we have developed Optotracing as the first non-disruptive technique by which the spatial localization of carbohydrates and other biomacromolecules can be visualized within native tissues and pulp. Confocal microscopy of native plant biomass stained by Carbotrace 680 generates a visual map of the tissues' lignocellulose anatomy at sub-cellular resolution. This provides a comprehensive understanding of the distribution pattern of cellulose and lignin, thus the molecular architecture of the plant biomass is directly visualized. Also, the physical and chemical changes of the biomass at each step of the defibrillation process can be analyzed at sub-cellular level using microscopy and spectroscopy [1-3]. This includes successive fractionation of the biomass into different cell types, such as libriform fiber cells and vessel elements. Also, different hierarchical structures such as delaminated fiber cells, and cell walls defibrillated into different cellulosic substructures, such as fibers, and fibrils can be observed. Our patent-protected method for non-destructive fiber analytics provides unprecedented details across all hierarchical structures of lignocellulosic materials, presenting a game-changing potential as an enabling technology for non-disruptive fiber analytics in research and industry alike.

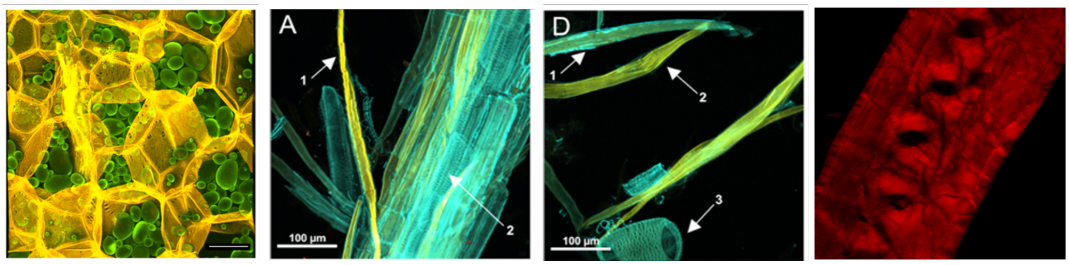

Figure 1. Confocal fluorescence microscopy visualizes carbohydrate and lignocellulose anatomy in

plant tissues / materials. Carbotrace 680 shows (1) cellulose (yellow) in the cell walls of potato parenchyma cells, starch (green) in intracellular granules ([1]). (2, 3) Cellulose (yellow) and lignin (blue) in samples at different stages of the defibrillation process ([2]). (4) Cellulose (red) in a fiber cell at high-resolution

[1] Choong, F.X., Lantz, L., Shirani, H., Schulz, A., Nilsson, K.P.R., Edlund, U., Richter-Dahlfors, A., *Cellulose* **2019**, 26:4253–4264

[2] Schmidt, A.E.M., Choong, F.X., Richter-Dahlfors, A., Edlund, U., *Adv. Sustainable Syst.* **2024**, 8, 2300632

[3] Wahlström, N., Edlund, U., Pavia, H., Toth, G., Jaworski, A., Pell, A.J., Choong, F.X., Shirani, H., Nilsson, K.P.R., Richter-Dahlfors, A., *Cellulose*. **2020,** 27:3707–3725

O33.2 - Chemis-tree Engineered Sandwich Composites

Textile, Pulp, Paper & Packaging
Materials & Engineering

Chemis-tree engineered sandwich composites

Debabèche, N.[a], Wagner, M[b]., Jiang, Q.[a] Feist, F[b], Bismarck A.[a,c*]

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[b] *Vehicle Safety Institute, Graz University of Technology, Inffeldgasse 13/6, 8010 Graz, Austria*

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Pulp foams are a potential alternative to porous polymers; however, their poor mechanical properties limit their application to packaging materials. We utilised the sandwich composite approach to produce panels (370 mm x 300 mm x 20 mm) comprising of pulp fibre foams and kraft liner papers to improve the mechanical properties of pulp fibre foams. Two types of sandwich structures are produced to improve the mechanical properties of pulp fibre foams: foam core sandwich panels and stiffened sandwich composites. The resulting sandwich structures materials have apparent densities ranging from 80 kg/m^3 to 161 kg/m^3. The mechanical properties are assessed in compression, three-point bending and double lap shear loading conditions. We show that pulp fibre foam sandwich structures possess significantly higher compression and flexural moduli and strengths when compared to pure pulp fibre foams. Stiffening the pulp fibre foam core further by incorporation of kraft liner paper stiffeners results in even higher mechanical, including lap shear, properties.

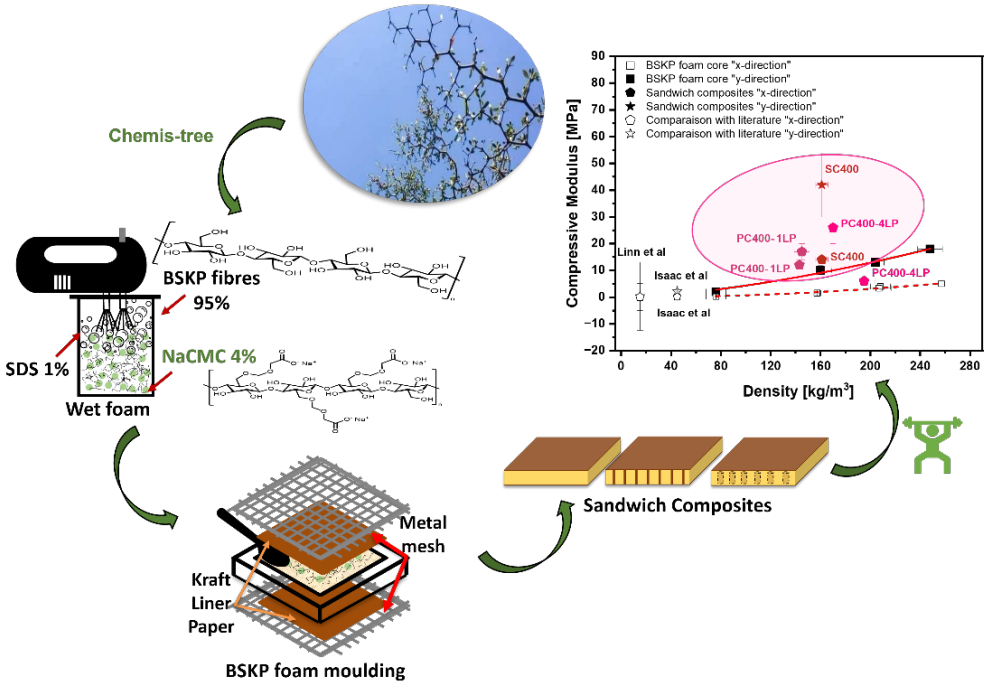

Figure 1. Graphical abstract of the Sandwich Composites.

O33.3 - Water addition process impact on thermo-pressed cellulose mattress: the role of bound and free water on cellulose fibers drying.

Textile, Pulp, Paper & Packaging
Materials & Engineering

Water addition process impact on thermo-pressed cellulose mattress: the role of bound and free water on cellulose fibers drying.

Bernard-Catinat, M.*[a], Bras, J.[a, b], Mauret, E.[a], Coussot, P.[c], Maillet, B.[c]

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[b] Institut Universitaire de France (IUF), Paris, France

[c] Laboratoire Navier (Ecole nationale des ponts et chaussées, CNRS), Univ. Gustave Eiffel, Champs sur Marne, France

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Single-use plastic packaging has been produced and used to protect consumer goods for decades, and poses serious end-of-life problems. To address this, authorities have enacted restrictions. In the field of rigid packaging, several alternatives have been found and cellulose stands out as a widely produced, recyclable biopolymer.

Amongst these alternatives, research has focused on molding cellulose, studying raw materials and process parameters in wet- and dry-end molding [1][2]. The present research aims to explore, for the first time, the impact of water in these processes. To this end, a pilot-scale molding machine was utilised to produce wet cellulose mattresses, whilst mechanical defibration was employed to produce dry cellulose mattresses. The water content of the wet cellulose mattress resulted from fiber suspension filtration, while the dry mattress was subjected to water spray addition to achieve a similar water content. Subsequent to this, the samples were then subjected to identical drying conditions, with the overarching objective being to comprehend the impact of water incorporation within the fiber network and the resulting materials were characterized accordingly. The morphology and surface properties of the final materials were examined using scanning electron microscopy and optical profilometry. Finally, a comparative analysis of the physical and mechanical properties (such as air permeability, tensile or bending strength) from both processes, utilizing the same raw material and optimized parameters, was conducted. As both processes result in cellulose matrices with similar overall water content, but differ in the way water interacts with the fibers, it is crucial to distinguish bound from free water within the fiber network. To this end, nuclear magnetic resonance (NMR) relaxometry was used to analyze the distribution and mobility of water, leading to a better understanding of the role of water in binding fibers during the drying [3].

[1] Pasquier, E.; Skunde, R.; Ruwoldt, J. *J. Bioresour. Bioprod*. **2023**, *8* (4), 408–420.

[2] Pasquier, E.; Mörseburg, K.; Syverud, K.; Ruwoldt, J. *J. Nat. Fibers.* **2024**, *21* (1), 2409890.

[3] Yan, L.; Zou, Y.; Gil-Roca, J.; Maillet, B.; St-Michel, B.; Coussot, P. *Phys. Rev. Appl*. **2025**, *23* (1), 014073.

Parallel session 34 - Chemistry, Biology & Physics

2025-08-28
11:30 - 12:30
Parallel session 34 - Chemistry, Biology & Physics

O34.1 - LONGITUDINAL ORDER IN CELLULOSE: METHODOLOGY AND PERSPECTIVES

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Longitudinal order in cellulose: methodology and perspectives

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Whereas the concept of crystallinity is routinely used on powder diffractograms, this work explores the possibility to get a further insight into the longitudinal arrangement of cellulose. In order to do so, the materials can either be measured in reflection on highly textured samples, or equivalently in symmetrical transmission. These measurements produce detailed diffractograms of the *00l* reflections up to $l = 10$ and the diffractograms could seem unfamiliar even to the experienced cellulose scientist. The results need careful treatment and corrections because the peaks are narrow and instrumental broadening becomes important. It is then shown that the longitudinal order as measured using this method provides a wealth of information such as the crystallite sizes, the microstrains and the macrostrains of each phase. Lineshape analysis using the Williamson-Hall approach and the Hosemann theory was performed on the flax sample. The coexistence of three degrees of orders with the exact same periodicity has been demonstrated for dried flax fibres and fir, which seems to indicate that cellulose is self-arranging in three universal forms of order across different *taxa*, albeit in different proportions. Novel results will also be presented in order to further explore the importance of the initial drying of fresh tissues on the final structuration of the cellulose.

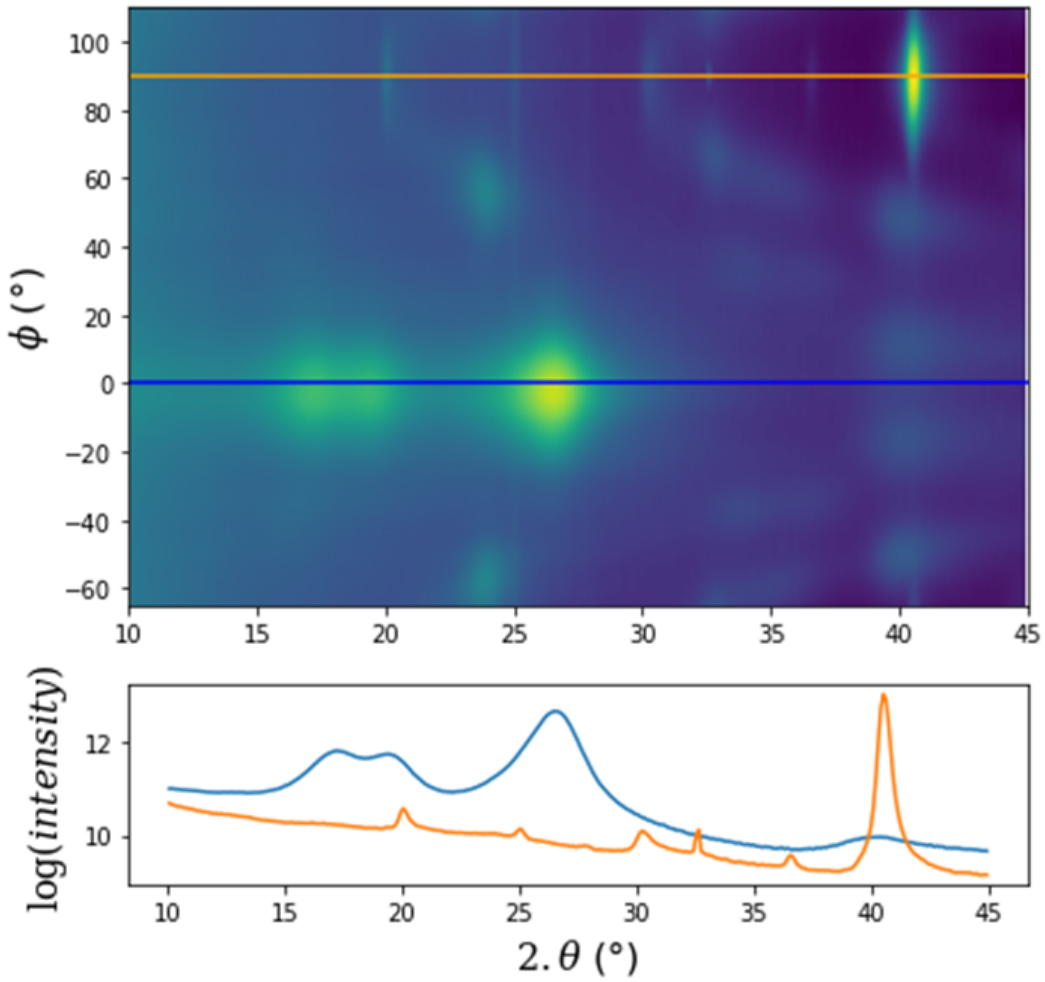

Figure 1. Example of a unidirectional fibre bundle measured in symmetrical transmission by performing multiple scans at various azimuthal angles (Φ). One notices the excellent amount of signal of the *00l* reflections in the meridional profile (orange profile). One can also see the clear separation of the *102* reflection from the meridional *002* reflection.

[1] Duchemin, B. « Longitudinal Orders in the Flax Cell Wall Re-Examined by Lineshape Analysis of the X-Ray Diffraction *00l* Profile up to $l = 10$ ». Cellulose 30, nº 13 (2023): 8169-84. https://doi.org/10.1007/s10570-023-05421-3.

O34.2 - THE QUANTITATIVE MOLECULAR WEIGHT-ANTIMICROBIAL ACTIVITY RELATIONSHIP FOR CHITOSAN

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

The quantitative molecular weight-antimicrobial activity relationship for chitosan

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Chitosan and its derivatives are known to inhibit the growth and eliminate pathogenic microorganisms, including bacteria and fungi. While the molecular weight (Mw) of the polymer significantly influences antimicrobial activity, the precise relationship between molecular weight and this activity remains unclear. Our recent study [1] demonstrated that the efficacy of *N*, *N*, *N*-trimethyl chitosan (TMC) against *S. Aureus* rises with Mw up to a critical molecular weight for maximum activity (CMW). Beyond this threshold, further increases in Mw did not impact the activity. Subsequent review [2] suggested that this relationship might be a consistent trend for chitosan and its derivatives, based on data from previous publications.

This study aimed to investigate if literature data can be fitted to a QSAR equation that describes the relationship between antimicrobial activity and molecular weight.

Drawing inspiration from Kubiniy's bilinear quantitative structure-activity relationship equations [3], we formulated a bilinear equation to elucidate the molecular weight-antimicrobial activity association for chitosan and its derivatives.

To encapsulate the bilinear relationship between molecular weight and activity based on the measured minimum inhibitory concentration (MIC) of the polymer, we introduced Equation 1:

$$Logleft(frac{1}{MIC} ight) = A_{max} + frac{left(A_{max}{- A}_{min} ight)}{CMW} imes Mw - Logleft(frac{10^{frac{A_{max}}{CMW} imes Mw}}{10^{frac{{ A}_{min}}{CMW} imes Mw}} + frac{10^{ A_{max}}}{10^{A_{min}}} ight)$$

The shape of the graph described by the equation is governed by three constants. The CMW is the critical molecular weight for maximum activity, A_{max} (MIC_{min}) represents antimicrobial activity when Mw>CMW, and A_{min} (MIC_{max}) is the projected activity as Mw approaches zero.

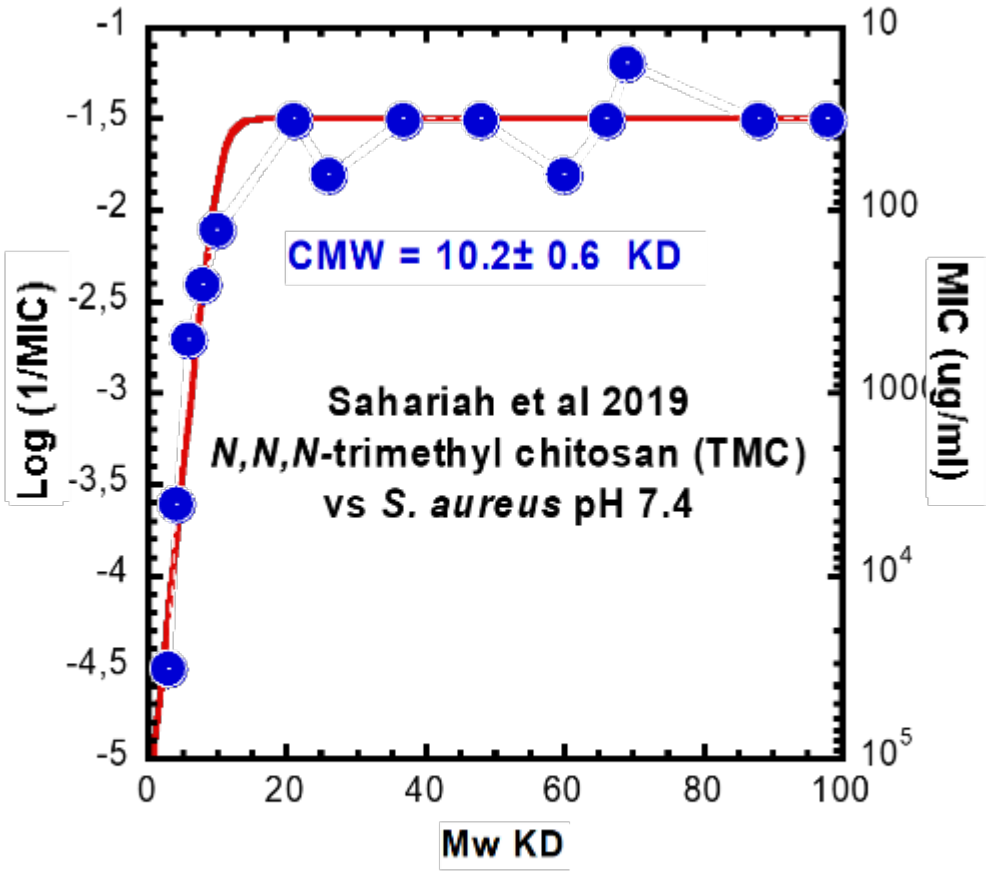

Figure 1) Example of the fitting of our published data to equation 1.

Twenty-nine datasets from studies published between 1984 to 2019, providing MIC values for chitosan and its derivatives relative to MW, were used for the analysis. We used the KaleidaGraph Software for least-squares fitting, resulting in excellent conformity to the equations across datasets (Example shown in Figure 1 [4]). For datasets with suitable fits and at least three values on either side of CMW, CMW values ranged from 4 to 10 KD.

The study showed that there is a bilinear relationship between the molecular weight of chitosan and chitosan derivatives and antimicrobial activity. This type of relationship may exist for other biological properties of chitosan and may also apply to other polysaccharides.

Acknowledgment: Icelandic Technical Development Fund (Rannis Grant: 2112860-0611)

[1] Sahariah et al. Int. *J. Mol. Sci*. **2019**, 20,1743

[2] M. Masson, Chitosan for Biomaterials iii: 2021, 131

[3] Kubiny. *J. Med. Chem.* **1977**, 20, 625

[4] M. Masson, Carbohyd. Polym. **2024**. 337, 122159

O34.3 - ADVANTAGES OF CHITOSAN STANDARDS IN THE DETERMINATION OF MOLECULAR WEIGHT

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Advantages of chitosan standards in the determination of molecular weight

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Molecular weight is an important parameter of chitosan, as it directly influences its properties depending on the chain length. Gel permeation chromatography (GPC) is a versatile tool to analyse the molecular weight. However, there is no universal international norm for measuring it, as for example the ASTM demands a multi angle light scattering (MALS) detector for molecular mass detection, while the USP monograph includes a method for determining the molar mass by using a Refractive Index (RI) detector. There are also variations in the column, chosen solvent, concentration etc. It is therefore imperative to develop a system, which can be used universally under several norms with as little deviation as possible.

Unlike MALS detection, RI-detection is a relative technique, requiring the use of a reference material with a known molecular weight (determined by the absolute light scattering method), such as the polymers pullulan, polyethylene glycol (PEG) or polyvinylpyrrolidone (PVP). Comparisons of chitosan molecular weight results obtained using RI detection with any of the aforementioned standards and light scattering show significant discrepancies, suggesting that conventional standards are inadequate for accurately determining the chitosan molecular weight.

Reasons are differences in their chemical structure, leading to different interactions with the GPC column and resulting in high deviations between the molecular weight as determined by light scattering and by RI detection.

In the presented work a GPC-standard based on chitosan was developed to give chitosan researchers the ability to determine its true molecular weight, even if a MALS detector is not available. This innovation lays the foundation to modify or update the current inconsistent methods in different official monographs or standard methods.

Using chitosan standards ranging from 16 to 618 kDa and validated methods, deviations of less than 20 % can be achieved between light scattering and RI detection across the whole molecular weight spectrum of chitosan.

Parallel session 35 - Chemistry, Biology & Physics

2025-08-28
11:30 - 12:10
Parallel session 35 - Chemistry, Biology & Physics

O35.1 - OLEYL-HYALURONAN: FROM SELF-ASSEMBLY AND INTERACTIONS TO ANTIMICROBIAL AND WOUND HEALING APPLICATIONS

Polysaccharide Colloids
Chemistry, Biology & Physics

Oleyl-Hyaluronan: From Self-Assembly AND INTERACTIONS to Antimicrobial and Wound Healing Applications

Sita, J.*[a,b], Čepa, M.[a], Velebný, V.[a],Ondreáš, F.[a,b]

[a] Contipro a.s., Dolní Dobrouč, Czechia

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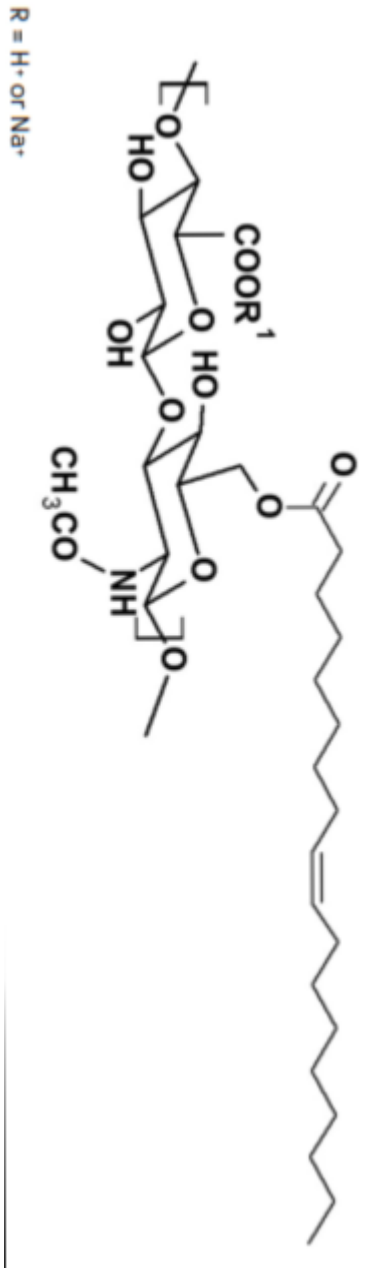
*jaroslav.sita@contipro.com

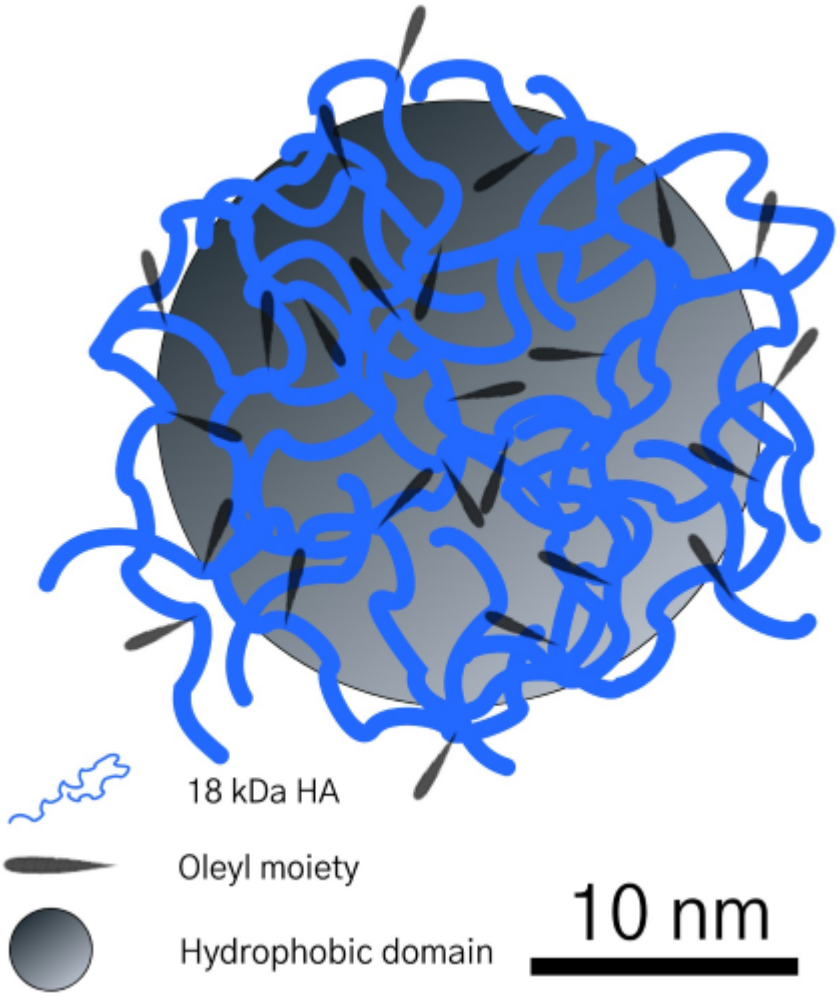
Hydrophobically modified hyaluronan (H-HA) self-assembles into aggregates in aqueous environment. Hydrophobic domains are present within these aggregates, allowing the encapsulation of hydrophobic compounds. The hydrophilic HA shell ensures good biocompatibility of the material in the body while enabling HA-specific targeting [1]. Therefore, these materials are promising as active substance carriers for cosmetics and pharmacy. Understanding its aggregation and interactions with biomolecules is crucial for optimizing drug delivery applications. In this study, we investigated the self-assembly of oleyl-hyaluronan (O-HA) in different aqueous environments and its interactions with proteins and penetration of active compounds into cells and skin.

O-HA's self-assembly was analyzed using dynamic light scattering (DLS), atomic force microscopy (AFM), scanning electron cryomicroscopy (cryo-SEM), fluorescence spectroscopy, rheology, and small-angle X-ray scattering (SAXS). Ionic strength significantly influences the formation of aggregates and their hydrophobic domains, with various salts enhancing aggregation compared to demineralized water due to charge screening effects [2]. Furthermore, the better self-assembled structures encapsulated more active compounds, such as curcumin and antifungal agents, and helped them penetrate the skin and into the cells. Interestingly, O-HA enhanced penetration into the skin not only for hydrophobic drugs but also for hydrophilic drugs. Loaded O-HA showed wound healing and antimicrobial effects *in vitro*.

Interactions with proteins, which are considered a bottleneck in carriers' applications, were assessed using isothermal titration calorimetry (ITC), rheology, and Förster resonance energy transfer (FRET). Three interaction regimes dependent on O-HA and bovine serum albumin (BSA) molar ratio were found and correlated well with skin penetration efficiency [3].

Our findings provide insight into the design of polysaccharide-based drug carriers with tailored aggregation and active compound delivery properties. The ability of O-HA to improve skin and cell penetration makes it a valuable material for various applications.


R = H+ or Na+
HO
COOR1
O
HO
OH
O
O
CH3CO
NH
O
O
O


18 kDa HA
Oleyl moiety
Hydrophobic domain
10 nm

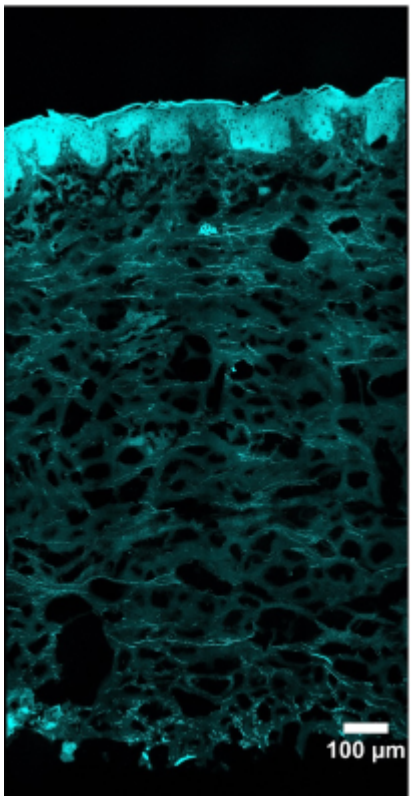

100 µm

Figure 1. O-HA's self-assembly and penetration of curcumin loaded O-HA into *ex vivo* porcine skin (right) evaluated by confocal fluorescence microscopy.

[1] Fu, C.P.; Cai, X.Y.; Chen, S.L., *Polymers* **2023**, *15*, 2317

[2] Ondreáš, F.; Dušánková, M.; Sita, J., et al. *Appl. Surf. Sci.* **2021**, *546*, 149161

[3] Ondreáš, F.; Sita, J.; Čepa, M., et al. *Appl. Surf. Sci.* **2022**, *593*, 153440

O35.2 - UNDERSTANDING INTERACTIONS OF PHARMACEUTICAL POLLUTANTS WITH CELLULOSIC MATERIALS

Chemistry, Biology & Physics

Understanding interactions of pharmaceutical pollutants with cellulosic materials

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**maija.vuoriluoto@vtt.fi*

The accumulation of pharmaceutical pollutants in aquatic systems, soil, and air is a major global concern due to the inability of conventional membrane processes to sufficiently remove, eliminate, or biotransform most of these substances.(Das 2017; Poerio et al. 2019) Understanding the interfacial interactions between the cellulosic materials and pharmaceutical residues (anti-inflammatories and estrogenic compounds) can facilitate the development of novel strategies for sustainable high-efficiency water purification technologies with the potential for controlled affinity and selective capture and degradation of the pollutants needed because of health impacts and diminishing freshwater resources worldwide. In this research, the interaction mechanisms of pharmaceutical pollutants (ibuprofen (IBP) and naproxen (NPR) (anti-inflammatory compounds) and 17α-ethinylestradiol (EE2) (estrogenic compound)) with cellulosic materials were examined using adsorption experiments with Surface Plasmon Resonance (SPR) technique (Fig. 1). The goal was to identify the key factors affecting the affinity between the cellulose materials and pollutants in a systematic fashion using real-time adsorption monitoring, which is not typically feasible with more traditional adsorption studies. In addition, the aim was to investigate the effects of modifying e.g., the surface energetics of the cellulosic substrates on pharmaceutical adsorption. Cellulosic ultrathin films (thickness ~10–20 nm) enable monitoring of pharmaceutical adsorption behavior and interactions *in situ* with SPR technique. Contact angle (CA) measurements were performed to investigate the influence of surface energy on interactions. The influence of pH and adsorbate concentration on adsorption behavior was also investigated with SPR, and the acquired data were fitted to the Langmuir adsorption model. Based on the results, highly hygroscopic and negatively charged nanocellulose surfaces showed low affinity for drugs, while regenerated cellulose and cellulose derivatives exhibited higher adsorption capacity.

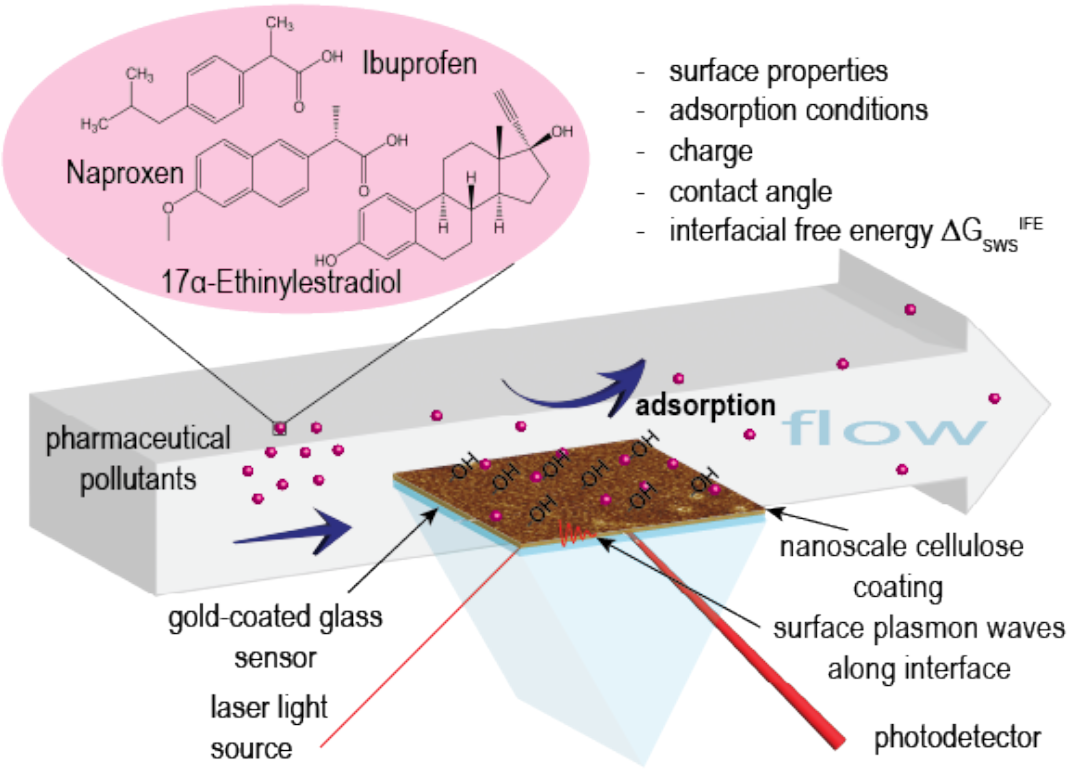

Figure 1. Schematic representation of pharmaceutical pollutant adsorption studies utilizing cellulosic ultrathin films with Surface Plasmon Resonance (SPR).

[1] Das, S. (2017) Ch. 5 Micropollutants in Wastewater: Fate and Removal Processes. In: Ray NM (ed). IntechOpen, Rijeka, 2017

[2] Poerio, T.; Piacentini, E.; Mazzei, R., *Molecules* **2019**, 24, 4148.

Parallel session 36 - Chemistry, Biology & Physics

2025-08-28
11:30 - 12:30
Parallel session 36 - Chemistry, Biology & Physics

O36.1 - PREDICTION OF CONTROLLED RELEASE FROM MATRIX TABLETS CONTAINING HPMC

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Prediction of controlled release from matrix tablets containing HPMC

Knarr, Matthias [*a]; Rogers, True L.[b]

[a] PS Biopolymer GmbH & Co. KG, R&D Polymer Synthesis & Modification, August-Wolff-Str. 13, 29699 Walsrode, Germany

[b] IFF Pharma Solutions, 1803 Larkin Center Drive, Midland, MI 48642 USA

Corresponding author (*): Matthias Knarr Matthias.Knarr@iff.com

Controlled release (CR) from a hydrophilic matrix tablet is mechanistically governed by formation of a robust enveloping hydrogel layer through which the active pharmaceutical ingredient (API) is released over time. Formation of the enveloping swollen layer is imparted by Hydroxypropyl methylcellulose (Hypromellose or HPMC) as the functional excipient of choice.

A new characterization technique, the so-called powder dissolution temperature (PDT), has recently been published. This PDT technique has been found to correlate HPMC attributes to CR performance. Additionally, this technique allows the differentiation of various chemistries of cellulose ethers and mechanistically elucidates why HPMC 2208 is the primary excipient of choice for CR performance [1] [2].

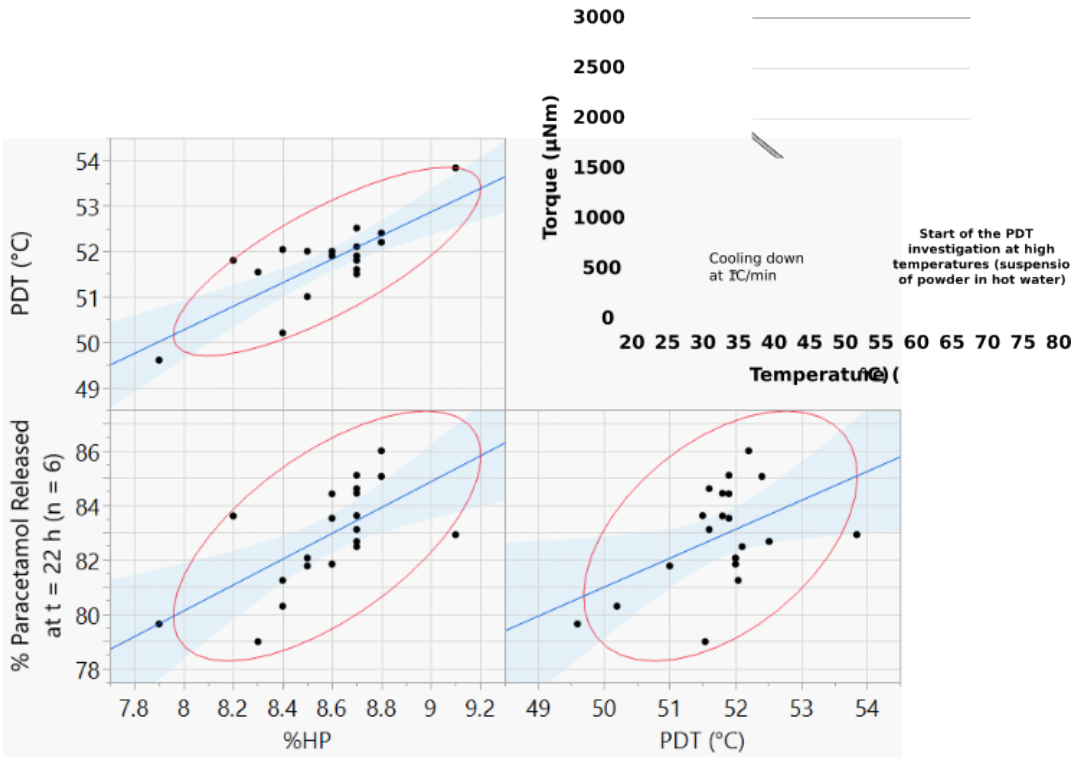

Figure 1. Illustration of the powder dissolution temperature (PDT) principle and its correlation to CR performance

[1] Knarr, M., Rogers, T.L. How Advanced Excipient Knowledge is Shaping the Future of Controlled-Release Formulation, Drug Development & Delivery October **2024** Vol 24 No7, p 36

[2] Knarr, M., et al., Investigation and rank-ordering of hydroxypropyl methylcellulose (HPMC) properties impacting controlled release performance. Journal of Drug Delivery Science and Technology, 2025. 104: p. 106425.

O36.2 - UCST gelation type of 4-O-methyl-D-Glucurono-D-xylan (MGX) from hardwood in aqueous media

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

UCST gelation type of 4-O-methyl-D-Glucurono-D-xylan (MGX) from hardwood in aqueous media

Buret R.*[a], Madau M.[a], Rihouey C.[a], Dulong V.[a], Le Cerf D.[a], Chaleix V.[b], Picton L.[a]

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Xylans constitute up to 90 % of hardwood hemicellulose [1]. They represent interesting materials to valorise [1] from wood industries in a bio-economic context. In this sense, our project (ANR Hydroxyl-PACT) deals with the development of antibacterial hydrogels made of xylans extracted from Beech (hardwood) located in Limousin (France). The chemical structure of the xylan used in this study corresponds to 4-O-Methyl-D-Glucurono-D-Xylan (MGX), with a deacetylated β-1,4 xylose backbone, and occasional uronic acid moieties (around 1 uronic acid every 7 xylose units). Phenolic compounds like ferulic acid [2] or lignin residues attached to the backbone were also reported, as is often the case in the literature [3]. These residues provide xylan chains with an aggregative behaviour (hydrophobic and/or hydrogen bonds associations) in aqueous media [4]. This phenomenon was observed by our team, which aimed at optimising the dissolution of MGX in aqueous solutions (in pure water at high temperature for instance). Furthermore, after preconditioning MGX solutions at 80 °C above a certain critical concentration, a reversible sol/gel transition with a strong hysteresis (Figure 1) was evidenced when decreasing the temperature below a certain threshold. This ‘UCST like behaviour’ has also been observed for other polysaccharides like kappa-carrageenan [5]. Our presentation will deal with the influence of factors such as MGX concentration or salt influence on the sol-gel transition and structure.

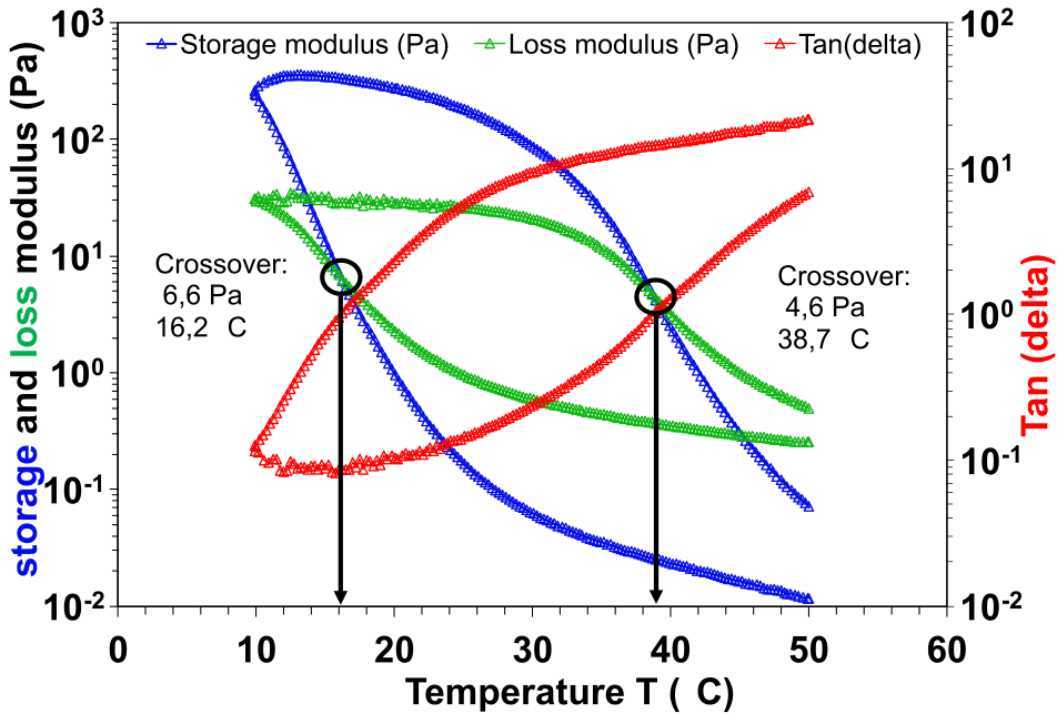

Figure 1: rheological observation of both sol/gel and gel/sol transitions of a MGX solution (150 g/L in H2O MQ) during a temperature ramp between 50 to 10 °C going back and forth (heating rate: 0.5 °C/min; stress: 0.1 Pa; frequency: 1 Hz)

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O36.3 - FUCOIDAN AND K-CARRAGENAN-BACTERIAL CELLULOSE FILMS: IN SITU SYNTHESIS AND CHARACTERIZATION

Chemistry, Biology & Physics

Fucoidan and k-carragenan-Bacterial cellulosE FILMS: *In Situ* Synthesis and Characterization

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The widespread reliance on non-biodegradable plastics presents significant environmental challenges, necessitating the development of sustainable alternatives. Bacterial cellulose (BC) emerges as a promising sustainable alternative due to its excellent mechanical properties and Generally Recognized as Safe (GRAS) status. However, its industrial applicability can be enhanced by modifying its physicochemical properties [1]. This work aimed to enhance BC's physicochemical properties via *in situ* incorporation of, κ-carrageenan or fucoidan, during its biosynthesis by *Komagataeibacter hansenii*. Composite films were synthesized in Hestrin-Schramm medium containing 0.5% (w/v) polysaccharide under static conditions (30°C, 72h), purified, and characterized.

Structural, mechanical (tensile, puncture), water interaction (solubility, water retention, water vapor permeability), and optical properties were evaluated. FTIR-ATR confirmed the successful incorporation of both κ-carrageenan and fucoidan into the BC matrix, evidenced by characteristic polysaccharide peaks in composite spectra. Mechanically, polysaccharide incorporation significantly increased film flexibility (elongation at break, %E, increased from ~0.4% for BC to ~1.0% for BC-Carrageenan (BC-C) and ~1.6% for BC-Fucoidan (BC-F), $p<0.05$), but decreased tensile strength and puncture resistance, compromising overall mechanical strength.

Water solubility was significantly increased for both composites (BC ~11%; BC-C ~43%; BC-F ~25%, $p<0.05$). Carrageenan significantly enhanced water retention capacity (BC ~313%; BC-C ~1681%, $p<0.05$), while fucoidan showed no significant effect. WVP remained statistically unchanged ($p>0.05$) for all films (~2-3.5 x 10^{-11} g/s·m·Pa). All films exhibited excellent UV-blocking capabilities across UV-C, B, and A ranges. Carrageenan significantly increased transparency and decreased opacity, while fucoidan significantly decreased opacity without affecting transparency significantly.

These findings highlight the potential of BC-algal polysaccharide composites as advanced

biomaterials with tunable mechanical, water-responsive, and optical properties. The enhanced elongation at break properties, UV protection, and controlled water interactions broaden their applicability in diverse fields, including biomedical engineering, food packaging, wound dressings, smart coatings, and biodegradable electronic components. The ability to tailor BC properties through *in situ* modification provides a sustainable strategy for developing high-performance biomaterials.

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Parallel session 37 - Materials & Engineering

2025-08-28
11:30 - 12:30
Parallel session 37 - Materials & Engineering

O37.1 - EXPLOITING MARINE POLYSACCHARIDES FOR THE DESIGN OF MORE SUSTAINABLE THERMOSET CORK BASED MATERIALS

Sustainable Materials/Circular Economy
Materials & Engineering

EXPLOITING Marine Polysaccharides for the design OF MORE Sustainable thermoset cork based Materials

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Portugal is the leading producer and exporter of cork, a renewable material harvested from the bark of the cork oak (*Quercus suber L.),* a slow-growing evergreen tree native to the western Mediterranean region [1]. Cork is renowned for its excellent elasticity, low permeability to liquids and gases, acoustic and thermal insulating properties, and light weight, with its most valuable and traditional use being in the production of bottle cork stoppers [1]. In recent years, as a means of repurposing lower-grade cork that is unsuitable for stoppers, and taking advantage of its unique properties, cork has gained attention in the production of composite materials for a wide range of applications across the building, automotive, and aerospace industries, and also in the design and apparel sectors [1,2].

In this work, sustainable cork-based thermoset composites were prepared by blending cork granules with conventional thermosetting resins and marine polysaccharides, followed by hot compression molding to obtain the cork agglomerate materials (Figure 1). The incorporation of marine polysaccharides aims to increase the sustainability of these materials by replacing part of the thermosetting resins, reducing the reliance on synthetic materials [3]. This approach not only promotes sustainability, but also aims to improve the properties (e.g., mechanical properties) or impart novel functional features to the cork-based materials.

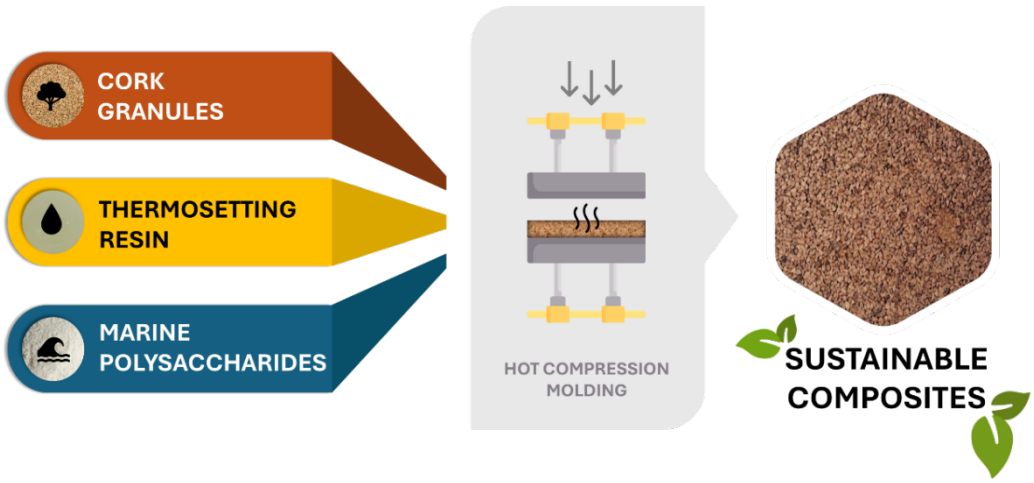

Figure 1. Scheme of the fabrication of cork-based thermosets with marine polysaccharides.

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Acknowledgments: This study was funded by the PRR – Plano de Recuperação e Resiliência and by the NextGenerationEU funds at Universidade de Aveiro, through the scope of the Agenda for Business Innovation "Pacto da Bioeconomia Azul" (Project no. 16 with the application no. C644915664-00000026) and the project CICECO–Aveiro Institute of Materials, UIDB/50011/2020 (DOI 10.54499/UIDB/50011/2020), UIDP/50011/2020 (DOI 10.54499/UIDP/50011/2020) & LA/P/0006/2020 (DOI 10.54499/LA/P/0006/2020), financed by national funds through the FCT/MCTES (PIDDAC). FCT is also acknowledged for the research contracts under the Scientific Employment Stimulus to C.V. (2021.01571.CEECIND) and C.S.R.F. (CEECIND/00464/2017).

O37.2 - PREPARATION OF HYBRID POLYSACCARIDE / METAL OXIDE MEMBRANES FOR APPLICATIONS IN CATALYSIS

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Preparation of hybrid Polysaccaride / metal oxide membranes for applications in catalysis

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Zinc oxide nanoparticles (ZnO-NP) are well-known for their wide application potential, for instance, in photocatalysis, waste-water treatment, cosmetics, or in the medical realm. This study aimed at immobilizing ZnO-NPs on polysaccharide-based substrates, including electrospun nanofibers and ultra-porous films, for generating eco-friendly and reactive biohybrid materials for catalytic applications. In this work, two methods of producing these materials were investigated.

In a first attempt, ZnO-NPs were prepared from zinc acetate through a simple precipitation method and subsequently immobilized on the different substrates. In the second method, the nanoparticles were synthesized directly on the membranes, which we prepared by electrospinning or solvent casting of cellulose acetate, alginate or chitosan. Both the surface morphology and chemistry, which were determined by the preparation technique and the selection of the polysaccharide, played an important role for the formation and stabilization the metal oxide nanoparticles. Furthermore, the influence of the reaction medium (ethanol and water) on the formation of ZnO-NP was examined. The results demonstrated that the synthesis in water resulted in the formation of mixed particles of zinc oxides and hydroxides.

The produced nanohybrid materials were analyzed by X-ray photoelectron spectroscopy (XPS) to monitor the conversion of the precursor salt into ZnO-NP. The characterization of the membranes' surface structure, and to confirm the presence of ZnO-NPs, was performed by scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). In future experiments, the catalytic properties of the hybrid membranes will be investigated to determine their efficacy in removing organic dyes or heavy metals from waste-water.

O37.3 - MULTI-SCALE INVESTIGATION OF THE EFFECT OF PHOTOCURABLE POLYETHYLENE GLYCOL DIACRYLATE ON THE SELF-ASSEMBLY OF CELLULOSE NANOCRYSTALS

Nanostructured Materials
Materials & Engineering

Multi-scale investigation of the effect of photocurable polyethylene glycol diacrylate on the self-assembly of cellulose nanocrystals (CNCs)

Lorenzo Metilli[a,b,*], Samuel Mandin[b], Ioanna Chazapi[c], Erwan Paineau[c], William Chèvremont[d], Nicolas Hengl[b], Frédéric Pignon[b], Bruno Jean[a]

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Adding photocurable polymers to aqueous suspensions of CNCs preserves their structural organization after processing, as recently demonstrated for nanocomposites with gradient chiral nematic structure produced by membrane ultrafiltration and UV-curing [1]. Nevertheless, understanding the physiochemical interactions between the nonionic polymer (PEGDA) and the CNCs is necessary to rationalise their structuring under external stimuli. In this work, the effect of increasing amounts of PEGDA (0.7 kDa) on the organisation of CNCs has been investigated with a multi-scale approach, including small angle X-Ray and Light scattering. The results showed a peculiar non-monotonic trend (Figure 1): at low PEGDA/CNC mass ratios (R_{PC}), the polymer adsorbed on the surface of CNCs, blurring their particle morphology and weakening their chiral strength (resulting in a looser cholesteric pitch). Further amounts (R_{PC}=1-1.5) increased the thickness of CNCs, with higher volume fractions and higher chiral strength (smaller pitch). Finally, above R_{PC}=2 (16 wt. %) the amount of PEGDA impacted also the properties of the medium. In fact, a lower dielectric constant increased the electrostatic repulsion between CNCs, while reducing further the pitch period. This complex trend was effectively captured by calculating the twist angle between CNCs, which could be used to describe the behaviour of CNCs suspensions in combination with other additives [2].

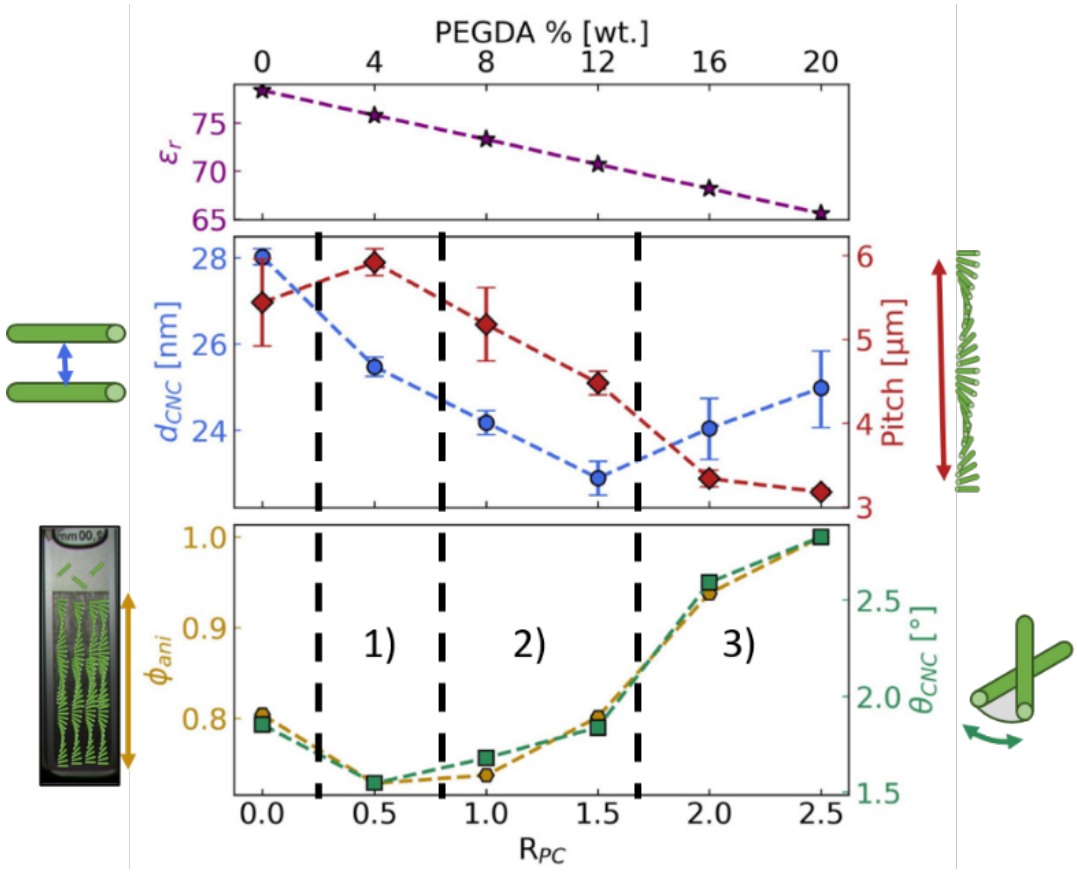

Figure 1. Multiscale behaviour of CNCs with added PEGDA: dielectric costant (ε_r, stars), interparticle distance (d_{CNC}, circles), cholesteric pitch (rhombi), anisotropic volume fraction (φ_{ani}, hexagons), twist angle (θ_{CNC}, squares). Numbers show the different adsorption regimes.

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Parallel session 38 - Materials & Engineering

2025-08-28
13:50 - 14:30
Parallel session 38 - Materials & Engineering

O38.1 - Surface-sensitive approach to investigate wood cell wall component interactions aimed for improving pulping process chemistry

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

SURFACE-SENSITIVE APPROACH TO INVESTIGATE WOOD CELL WALL COMPONENT INTERACTIONS AIMED FOR IMPROVING PULPING PROCESS CHEMISTRY

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Current megatrends are causing industries to shift towards lowering their carbon footprint, and the forest sector is at the forefront of this development. Due to the advance of industrial electrification and decarbonization of energy, the approach to reduce emissions by improving the yield and product quality of pulping processes is becoming more and more attractive. Against this backdrop, this work attempts to find new perspectives and directions to challenge the current pulping chemistry by taking inspiration from other fields of research, especially from plant physiology and modelling.[1,2]. This is approached by constructing surface-sensitive experimental models for investigating key wood cell wall components and their interactions with quartz crystal microbalance with dissipation monitoring (QCM-D). Here, ultrathin model surfaces are created and analyzed using chemically native-like softwood lignocellulosic components. Lignin surfaces are fabricated by adapting preparation protocols using mill wood lignin[3] and enzymatic mild acidolysis lignin[4]. Moreover, lignin-containing cellulosic surfaces are prepared using cellulose nanofibers[5] from thermomechanical pulp. This approach allows the *in situ* investigation of interactions between lignin, cellulose, hemicelluloses, and importantly, water, using the same scale as atomistic models with real materials and simplified, controllable conditions. Thus, the model surfaces act as an intermediate between fundamental cell wall knowledge and industrially relevant pulping processes, giving further insight on how to separate the lignocellulosic components more efficiently with new pulping chemistries.

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O38.2 - PROCESSING CONSISTENCY IN HIGH-PRESSURE HOMOGENIZATION AS A KEY FACTOR IN ENERGY AND QUALITY TRADE-OFFS OF NANOCELLULOSE PRODUCTION

Nanostructured Materials
Materials & Engineering

processing consistency in high-pressure homogenization as a key Factor in energy and quality trade-offs of NANOCELLULOSE PRODUCTION

Signori-Iamin, G.*[a], Juan Aguado, R.[a], Putaux, J-L.[b], Ferreira Santos, A.[c],Thielemans, W.[d],Delgado-Aguilar, M.[a]

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High-pressure homogenization (HPH) is one of the strategies applied to produce highly fibrillated cellulose nanofibers (CNFs). Although the interest over these nanomaterials are increasing, due to their versatility and excellent mechanical properties, their production via this route is energy-intensive, which limits large-scale applications. To tackle this challenge, this study investigated how processing consistency (0.5 to 3 wt.%) influences energy consumption and CNF properties during HPH of TEMPO-oxidized eucalyptus pulp. Across the different number of passes and pressures studied, three main levels were defined: i1 for 3 passes at 300 bar, i2 for 3 passes at 300 bar and 3 passes at 600 bar and i3 for 3 passes at 300 bar, 3 passes at 600 bar and 3 passes at 900 bar [1].

Results show that energy spent is initially determined by processing volume but later constrained by viscosity. One of the main findings was that processing samples at the same level (i.e. i1, i2 or i3) yielded CNFs with different properties, especially related to their morphology and rheology (analyzed at the same solid content). It was observed that higher consistency enhance fibrillation efficiency and promote the transformation from the micro to the nanoscale. A 1.5 wt.% consistency was identified as the most energy-efficient for producing highly fibrillated, transparent suspensions, whereas a 3 wt.% was more economical for lower-yield applications. A techno-economic analysis was also performed and showed that processing at intermediate consistencies can optimize cost-effectiveness by reducing transportation costs, which may offset increased energy demand. These findings provide valuable insights for improving the economic viability of CNFs, emphasizing the need to balance energy, quality, and transportation costs for scalable CNF production.

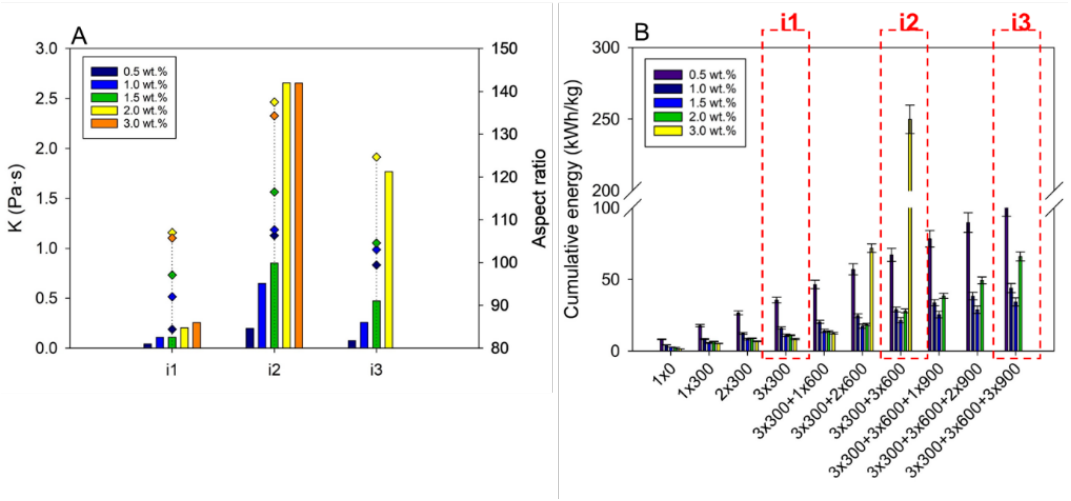

Figure 1. *K* parameter (from the Ostwald-de Waele fit) at 0.5 wt.% (bars) and aspect ratio (diamonds) as a function of intensity of fibrillation (A). Cumulative energy in kWh/dry kg as a function of number of passes and pressure in HPH and processing consistency (B).

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Parallel session 39 - Chemistry, Biology & Physics

2025-08-28
13:50 - 14:50
Parallel session 39 - Chemistry, Biology & Physics

O39.1 - Targeting active domain discovery of natural polysaccharide

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Targeting active domain discovery of natural polysaccharide

Kan Ding

Carbohydrate-Based Drug Research Center, CAS Key Laboratory of Receptor Research, State Key Laboratory of Drug Research, Shanghai Institute of Materia Medica, Chinese Academy of Sciences; Shanghai 201203, China

Abstract: More and more evidence suggest that natural polysaccharides show broad bioactivities with relative safety for potential new drug development. However, there are some challenges such as studies of target molecule discovery, quality control, pharmacokinetics, etc. need to be solved for the polysaccharide-based new drug development due the homogeneity and complex structure motif. Although the size of polysaccharide is also important to the interaction between polysaccharide and functional protein, in some cases, small size of sub-polysaccharide or even oligosaccharide may also be enough to bind the functional protein. However, the basic structural details of minimum size of the polysaccharide, so called active domain of polysaccharide need to be mapped before the leading compound to be determined for the new drug development. We show evidence firstly that natural polysaccharide does have such active domain by synthetic and biochemical methods. For example, polysaccharide RN-1 and LBP1C-2 from *Carthamus tinctorius* and *Lycium barbarum* have highly branched heptadecasaccharide and acidic 63-mer pectin or even small size saccharide （pentasaccharide or decasaccharide）active domain, respectively. Both polysaccharides and their derived oligosaccharides or sub-polysaccharide may bind to galactin-3 to inhibit pancreatic cancer growth or impede liver fibrogenesis. These studies may provide evidence to support polysaccharide-based new drug development.

Reference

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2. Hu C, Wu S, He F, Cai D, Xu Z, Ma W, Liu Y, Wei B*, Li T*, Ding K*. Convergent Synthesis and Anti-Pancreatic Cancer Cell Growth Activity of a Highly Branched Heptadecasaccharide from Carthamus tinctorius. Angew Chem Int Ed Engl. 2022 61(32): e202202554.

O39.2 - Investigation of intermolecular interaction between quinacridone pigment and polysaccharide nanofibers by gel-state NMR spectroscopy

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Investigation of Intermolecular interaction between quinacridone Pigment and POLYSACCHARIDE NANOFIBERS

by gel-state NMR spectroscopy

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Quinacridone is a common red–violet organic pigment. Like many other organic pigments, quinacridone is prone to aggregate via intermolecular hydrogen bonding and π–π stacking [1]. As a result, quinacridone molecules form small aggregates called primary particles, and primary particles form larger cluster called secondary particles. Because these aggregates cause undesired color change, inhibition of pigment aggregation is important issue.

Recently, we found that cellulose nanofiber (NF) suppress the aggregation of quinacridone in aqueous medium [2-3]. When quinacridone was dispersed in water, second particles with the diamerter in the micrometer range were formed. After mixining cellulose NF with quinacridone aqueous dispersion, quinacridone primary particles existed along cellulose NFs and did not aggregate [2]. Similar results were obtained when using chitosan [4] and lignocellulosic [5] NFs. These results indicated that NFs consisting of polysaccarides are potential materials for pigment dispersant. However, the mechanism how polysaccaride NFs inhibit the quinacridone aggregation has not been fully elucidated. The purpose of this study, therefore, to reveal the mechanism. Because the adsorption of quinacridone onto NFs was suggested to inhibit the quinacridone aggregation observed by SEM, we focused on the intermolecular interaction between quinacridone pigments and polysaccharide NFs.

Solution-state NMR spectroscopy is one of the methods to analysis intermolecular interactions. However, this method could not be applied to investigate the interaction between quinacridone and polysaccharides because they are insoluble in NMR solvents. Therefore, we instead used gel-state NMR method, which sample is swelled in solvents [6]. It was found that signals could be detected in the NMR spectra of quinacridone–NF mixtures by using gel-state NMR method. In the ^{1}H-H NOESY spectrum of quinacridone–cellulose NF mixture (1:9, w/w), the cross peaks between signals 11.9 and 8.6–7.2 ppm derives from NH and aromatic groups of qunacridone and signals around 3.3–3.4 ppm derived from H3 and H4 of cellulose were detected. It was considered that quinacridone

might be adsorbed onto cellulose NF via hydrogen bonding and CH–π interaction [2]. In the case of lignocellulosic NF, cellulose and hemicellulose were suggested to interact with quinacridone [5]. On the other hand, from ^{1}H NMR measurements, the adsorption of quinaridone onto chitosan was supposed to be induced by hydrogen bonding [4]. These results indicated that the intermolecular interaction between quinacridone and polysaccharides promote the adsorption of quinacridone onto NFs, but the adsorption site is different among polysaccharides.

This presentation provides a comparative overview of the interaction mechanism between quinacridone and different polysaccharide nanofibers, and discuss the extension of gel-state NMR methodology for probing such intermolecular interactions.

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O39.3 - Potential of glucuronoxylanases as a tool for deciphering the molecular structure of hardwood acetylated glucuronoxylan

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Potential of glucuronoxylanases as a tool for deciphering the molecular structure of hardwood acetylated glucuronoxylan

Teresa Perez, Alba de Sebastian, He Li, Francisco Vilaplana and *Pramod Sivan

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Glucuronoxylan (GX) represents the major hemicellulose component of hardwoods. It consists of a backbone of β-(1→4)-linked d-xylopyranosyl (Xyl*p*) units, which are occasionally substituted by α-(1 → 2)-4-*O*-methyl-d-glucuronic acid (MeGlcpA) and acetylated at the *O*-2 and/or *O*-3 positions with specific patterns of substitution, depending on the plant species and developmental stages [1,2]. Indeed, some plant species carry more complex substitutions, such as the galactose present in *Eucalyptus*, which hinders enzymatic deconstruction [3]. Mass spectrometry-based glycan sequencing is one of the major scientific methods for investigating the molecular structure of GX, and it involves use of potential *endo* β-xylanases to produce xylan oligomers carrying information about the pattern and position of backbone substitutions [1]. Despite of the importance of xylanase tolerance of the different side chain substitutions, there is little information available on the functional specificity of different *endo* β-xylanases for recognizing cleavage site on native acetylated GX. Therefore, the present study investigated the specific activity, quantity of released product and molecular structure of the oligosaccharide products released from acetylated and deacetylated GX purified from aspen wood by four different GH30 *endo* β-glucuronoxylanases belonging to GH30A, GH30B and GH30C families. The specific activity was highest for the deacetylated substrate for all enzymes except GH30C. Among the different enzymes, GH30B showed the highest release of hydrolytic products, while their major products were linear oligosaccharides. GH30C showed similar specific activity for both acetylated and deacetylated xylan, releasing uronilated XOs as major products. This indicated that GH30C was not specially hindered by acetylation compared to the GH30B and GH30A counterparts. The mass spectrometry-based profiling of products after enzymatic treatment revealed that the acetylation could be tolerated by all enzymes for cleaving the linear oligomers, however, GH30A and GH30C are more specific to glucuronic acid as major subsite for recognition of cleavage. In conclusion, this study identified GH30C as the most efficient glucuronoxylanase followed by GH30A to release diagnostic oligos with side chain substitutions suggesting their potential as a tool for deciphering the molecular architecture of hardwood xylan and biochemical conversion of GX for various applications.

Reference

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Parallel session 40 - Materials & Engineering

2025-08-28
13:50 - 15:10
Parallel session 40 - Materials & Engineering

O40.1 - FROM FEEDSTOCK TO FIBER - COMPARISON OF LYOCELL FIBER PRODUCTION FROM AGRICULTURAL FEEDSTOCK USING TWO ALTERNATIVE PULPING PROCESSES

Textile, Pulp, Paper & Packaging
Materials & Engineering

From feedstock to fiber - comparison of lyocell fiber production from agricultural feedstock using two alternative pulping processes

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The demand for cellulose fibers, both natural fibers as well as synthetic fibers, is increasing. This past year, the global market for cellulose fibers reached a volume of USD 32.6 billion, forecast to achieve a compound annual growth rate (CAGR) of between 7.6 % and 9.6 % by the beginning of the next decade [1,2]. In addition to a strong global growth in the textile industry, demand for biodegradable fabrics as a result of increasing environmental awareness is a key factor driving the growth of the market [1]. Against the backdrop of the negative environmental impact of market-dominating cotton production, the latter aspect can be met in particular by manmade cellulose fibers (MMCFs) [3]. Nevertheless, the market growth of the MMCFs submarket from 7.3 million t in 2022 to an expected 9 million t in 2027 is 4.3 %, and so below the forecast CAGR of the overall market [4]. This can be attributed to the fact that of the two major processes for obtaining MMCFs from cellulose, the viscose and the lyocell process, especially the second has the potential to meet market requirements in terms of fiber properties and ecological impact. However, the high and specific requirements placed on the pulp for this process limit its market expansion. The fact that pulp provision can barely be expanded through the processing of cotton linters and only at great expense through the pulping of wood justifies the exploration of the suitability of other raw materials [5]. In addition to the utilisation of used textiles, non-wood plants, in particular agricultural residues, are suitable feedstocks. Based on the lower lignin content and the easier accessibility of their substrate, non-wood feedstocks can be digested using significantly less energy and chemicals than wood, which enables the application of alternative digestion systems that have unattractive delignification potentials for the pulping of wood [6].

Proof of the suitability of this approach was provided by processing agricultural feedstocks to fibers of competitive properties. The production of dissolving pulp from three representative agricultural feedstocks was carried out using alkaline and acidic pulping processes in order to subsequently process them into lyocell fibers. With soda pulping as an old and fundamental process, and NBP pulping as a newly developed organosolv-process – firstly presented on last EPNOE Junior Scientist Meeting –, two environmentally friendly process routes with different approaches for the production of regenerated fibers are presented. While both processes are sulphur-free and characterised by a

comparatively low process engineering effort, they differ in addition to the pH value, the temperature and pressure range as well as the subsequent treatment stages. Advantages and disadvantages of both process approaches were evaluated with regard to process engineering effort, achievable yields and the resulting fiber properties. The final results underline the potential of alternative pulping processes and offer sustainable and environmentally friendly alternatives for efficient dissolving pulp production by using agricultural residues.

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[4] IMARC Group, *Cellulose fibers market*, 2022

[5] B. Kosan; K. Thümmler; F. Meister; K. Römhild, *Cellulose* 2024, 24, 1941–1955

[6] M.A. Azeez, *Pulp and Paper Processing* 2018, IntechOpen, London, 2018

O40.2 - CHEMICAL RECYCLING OF COTTON-POLYESTER TEXTILES VIA TEMPO-MEDIATED OXIDATION

Textile, Pulp, Paper & Packaging
Materials & Engineering

Chemical recycling of cotton-Polyester textiles via TEMPO-mediated oxidation

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We introduce a new approach to chemical recycling of cotton-polyester textiles, allowing recovery of both materials. In the method, cotton is disintegrated into nanocellulose by TEMPO-mediated oxidation and mechanical disintegration, retaining polyester in fibre form. The materials are separated leveraging their different surface energies: the hydrophobic polyester is flotated with air bubbles and recovered from the air-liquid interface, while the negatively charged TEMPO-oxidized nanocellulose dispersed in the liquid is recovered by centrifugation. SEM, and TGA analysis conclude that the cellulose is recovered as nanocellulose with high purity. Solid-state NMR shows successful introduction of carboxylate groups to the oxidized cellulose. NMR and GPC analyses confirms that the polyester remains chemically unchanged, which is key to the recycled material quality. Optical microscopy and TGA show a presence of cellulose in the recovered polyester fraction. However, by increasing the reaction time and temperature, the purity of polyester is significantly improved. Further optimization of the process is needed to improve the yield and purity of the material fractions. Nevertheless, the study demonstrates that the method holds significant potential for improving the economic viability of chemical recycling of cotton-polyester textiles through the recovery of both materials and ability to produce high value nanocellulose fraction from waste material.

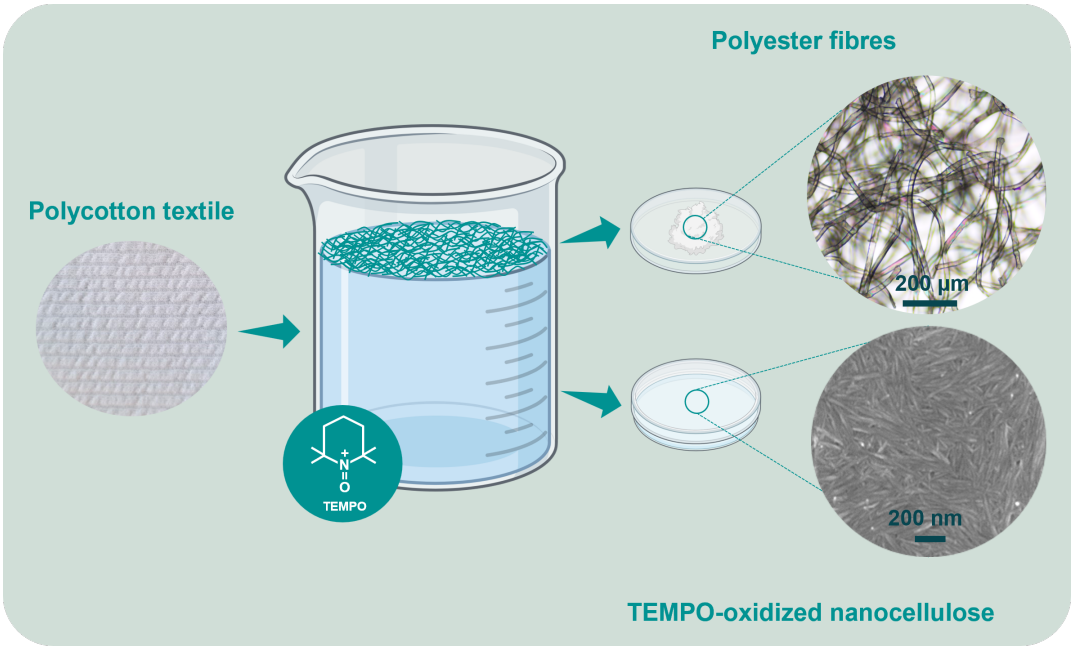

Figure 5 **Figure 1. High-level illustration of the chemical recycling process and the recovered fractions.**

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O40.3 - Enhanced rhodamine-6G uptake of lytic polysaccharide monooxygenase- treated lyocell fabric

Textile, Pulp, Paper & Packaging
Materials & Engineering

Enhanced rhodamine-6G uptake of lytic polysaccharide monooxygenase- treated lyocell fabric

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Abstract:

Regenerated cellulosic fibers, such as lyocell fibers, are fully biodegradable and of 100% natural origin [1]. With properties like high dry tenacity, they are widely used in many high-quality fiber applications. Among cellulosic fibers, lyocell fibers exhibit the highest dyeability, particularly with synthetic reactive dyes [1]. However, this results in high dye yields and significant amounts of reactive dye being lost in the effluent during the wash-off process, leading to energy-intensive water purification and environmental contamination [2]. Cationic dyes, which have a higher affinity for cellulosic fiber, can reduce dye wastage [3]. To enhance the affinity of lyocell fabric for cationic dyes, the fabric surface must be modified to introduce a negative charge. An elegant solution involves the use of the enzyme lytic polysaccharide monooxygenase (LPMO), which specifically carboxylates the C1 carbon position of the glycosidic bond without degrading the fabric [4]. This research demonstrates that dye retention of LPMO treated lyocell fabric can be increased by up to 75% for the cationic dye rhodamine-6G with LPMO loadings of ≤ 1%. Additionally, treated fabrics outperformed non-treated fabrics by achieving similar dye uptake with only half the amount of dye.

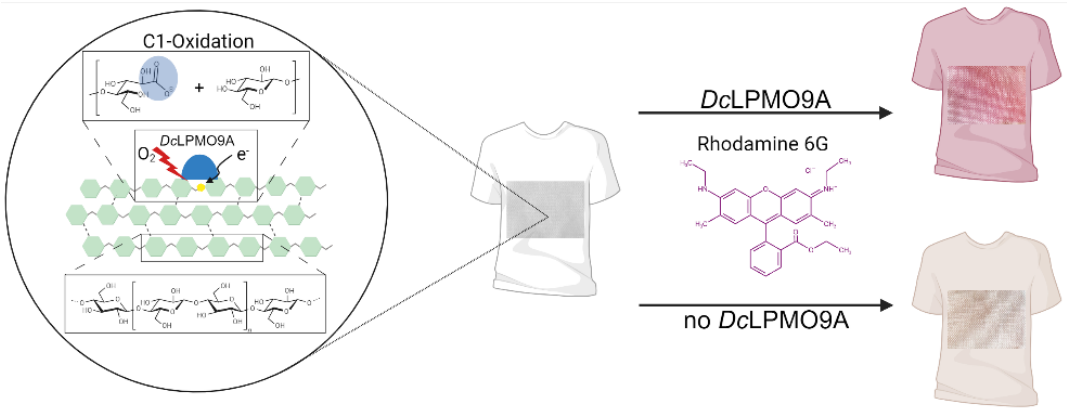

Figure 6 **Figure 1: Process Schematic of DcLPMO9A treatment of fabrics, carboxylate, and dye retention assay**

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[4] Mathieu, Y., Raji, O., Bellemare, A., Di Falco, M., Nguyen, T.T.M., Viborg, A.H., Tsang, A., Master, E., Brumer, H. 2023. Functional characterization of fungal lytic polysaccharide monooxygenases for cellulose surface oxidation. *Biotechnology for Biofuels and Bioproducts*, **16** (1), 132

O40.4 - Fiber development from polysaccharides applied to textiles and functional nonwovens

Textile, Pulp, Paper & Packaging
Materials & Engineering

Fiber development from polysaccharides applied to textiles and functional nonwovens

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The increasing demand for sustainable and biodegradable materials has driven extensive research into polysaccharide-based man-made fibers as alternatives to synthetic ones. Solution spinning – including the well-established wet spinning technique and the emerging solution blown method – is a fiber forming manufacturing process that allows for converting polysaccharide solutions (dopes) into textiles and biomedical materials. This oral presentation provides a comprehensive overview of recent advancements in solution spinning of polysaccharide-based fibers at RISE Research institutes of Sweden, focusing on both *green* and *blue* sources such as cellulose, chitin, chitosan, alginate and pectin, while elucidating the spinning process-structure-property relationships.

Solution spinning involves polysaccharide dissolution in appropriate solvents, followed by extrusion into a coagulation bath to solidify the fibers. In wet spinning, continuous individual filaments are produced and processed into yarns, while solution blowing results in a web-like structure of interconnected fibers, suitable for nonwoven applications, see Figure 1. Key factors influencing the fiber properties include polysaccharide type, solvent selection, coagulant composition, and post-spinning treatments, for instance to achieve desired mechanical properties of the fibers. Both techniques allow the incorporation of functional additives into the dope, which find more application in solution blown where high fiber strength is not a primary requirement.

At RISE, we have been investigating novel systems for cellulose dissolution and exploring the development of flame-retardant fibers [1]. Using solution blowing, biobased nonwovens containing encapsulated bioactives [2], including antimicrobials [3], have been developed for long term infection control and tissue engineering applications.

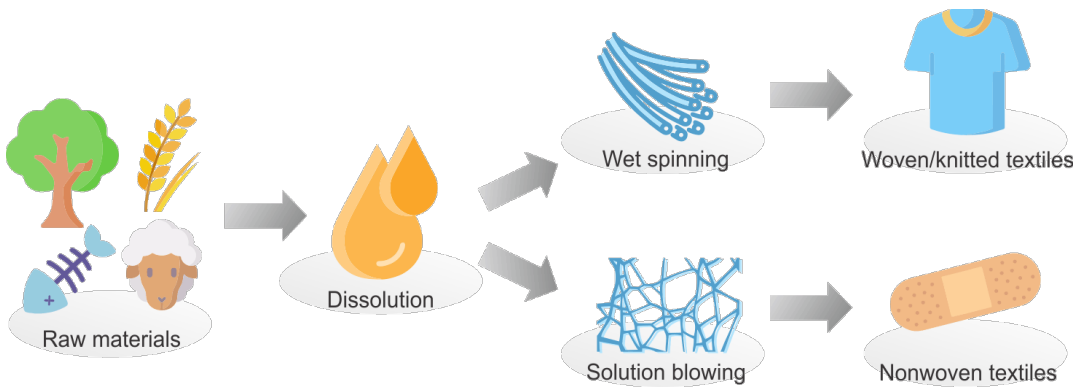

Figure 1. Schematic of wet spinning and solution blowing methods for the production of fibrous materials

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Parallel session 41 - Chemistry, Biology & Physics

2025-08-28
13:50 - 15:10
Parallel session 41 - Chemistry, Biology & Physics

O41.1 - Cracking Carbohydrates: Modern Methanolysis for Lignocellulosic Landscapes

Compositional Analysis
Chemistry, Biology & Physics

Cracking Carbohydrates: Modern Methanolysis for Lignocellulosic Landscapes

Markus Eder[a], Stefan Böhmdorfer[a], Stefanie Gross Belduma[a], Ivan Sumerskii[b], Antje Potthast[a*]

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Methanolysis is a well-established method for the detailed analysis of the sugar composition in lignocellulosic biomass.[1] While traditionally applied to purified pulp, its scope has recently expanded to more complex matrices such as plant gums and raw biomass, such as bamboo and corn stover, underscoring its broader potential for biomass characterization [2,3].

Methanolysis still poses several challenges. The resulting mixtures of methyl glycosides and esters of uronic acids that are obtained by depolymerization are complex. Since every monosaccharide gives four peaks in gas chromatography, a complete separation is hard to achieve. The overlapping chromatographic peaks—particularly in samples rich in pectins or lignin—complicate both quantification and compound identification [4]. Additionally, the commonly used derivatization process to introduce trimethylsilyl (TMS) substituent is highly sensitive to moisture: the resulting methyl glycosides can be unstable, and shifts in molar ratios have been reported due to partial degradation or rearrangement under non-ideal conditions [5]. Chromatographic performance is also influenced by the choice of derivatization strategy; for example, TMS derivatives tend to exhibit less interaction with stationary phases than acetylated compounds, which has a strong effect on the quality of separation [4].

To overcome these limitations, we focused on refining derivatization protocols, enhancing selectivity during separation, and coupling methanolysis with advanced detection strategies. The combined use of flame ionization detection (FID) and mass spectrometry (MS) has proven especially effective, improving both sensitivity and resolution in the analysis of complex biomass-derived sugar mixtures. These advancements reinforce methanolysis as a versatile and scalable tool for comprehensive biomass characterization. As a result, more accurate quantification of individual sugars is possible, and previously overlapping peaks can be effectively resolved—ultimately providing more reliable insights into the polysaccharide composition of complex samples.

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(5) Xiao, W.; Chen, X.; Zhang, Y.; Qu, T.; Han, L. Product Analysis for Microwave-Assisted Methanolysis of Lignocellulose. *Energy Fuels* **2016**, *30* (10), 8246–8251. https://doi.org/10.1021/acs.energyfuels.6b01186.

O41.2 - ENHANCED BEAUTY OF DUTCH ROSES: GREEN APPROACH FOR CELLULOSE NANOMATERIALS

Extraction & Purification
Chemistry, Biology & Physics

ENHANCED BEAUTY OF DUTCH ROSES: GREEN APPROACH FOR CELLULOSE NANOMATERIALS

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Roses hold deep symbolic and cultural significance in our society, representing emotion, expression, luxury, status, and historical symbolism. In the Netherlands, roses symbolize pride in the country's floriculture expertise and a deep-rooted appreciation for nature's beauty in everyday life. In 2023, Dutch rose growers sold approximately 496 million roses [1], and it is estimated to generate between 2460 and 7440 tons of organic waste, including leaves, thorns, stem trimmings, and wilted petals. This waste is rich in opportunities for polysaccharides nanomaterials. For instance, stem roses comprise around 48% of cellulose, 17% of hemicellulose, and 30% of lignin. Our research uses rose stems to produce cellulose nanofibrils (CNF) through a greener and more efficient process. The rose stems were subjected to an oxidative treatment of hydrogen peroxide and organic acids, generating potent radicals and breaking down and reducing the lignin content by up to 29%. This process eliminates the lignin and facilitates the production of CNF by adding charges on their surface. As a result of different organic acids, the CNF exhibited different fine diameters, high aspect ratio, and carboxyl content, proving a gel-like structure with shear-thinning behavior and excellent stability. Our method is an environmentally friendly process demonstrating rose stem waste's potential as a valuable raw material for producing CNF. This study contributes to waste valorization in the floriculture industry and optimizes processing conditions for the extraction and valorization of cellulose from different biomasses.

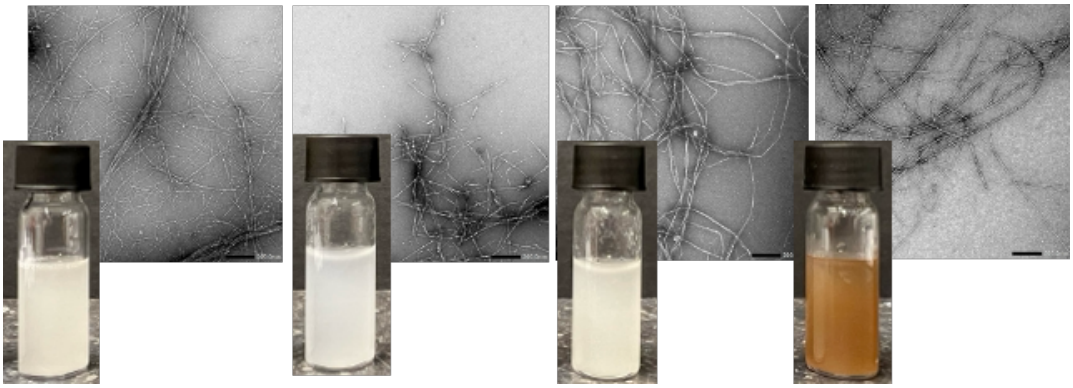

Figure 1. Suspensions and TEM images of CNF roses produced in this study.

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O41.3 - UNDERSTANDING THE COMPLEX FORMATION OF HEMICELLULOSE-POLYPHENOL ASSEMBLIES

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

Understanding the complex formation of hemicellulose-polyphenol assemblies

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The plant cell wall is a fascinating example of a perfectly optimized nanocomposite with highly tunable mechanical properties, resulting from a wide variability of complex microstructures formed by biomolecules (cellulose, hemicelluloses, pectins, lignin, proteins...). To better understand this architecture, simplified systems such as the cellulose-hemicellulose-polyphenol ternary model can be studied. In this context, we first established the phase diagram of the hemicellulose-polyphenol pair using xyloglucan and tannic acid as model molecules by characterizing their assembly through the variation of their concentrations and the ionic strength of the medium.

This phase diagram was obtained by following the system turbidity using droplet-based millifluidic setup that allowed us to identify two distinct regimes: a homogeneous phase of nanoparticulate complexes and a phase of macroscopic aggregates. As both states hold significant potential for the design of bio-based materials, we aimed to elucidate the mechanisms responsible of their formation using advanced techniques such as ITC, QCM-D, and DLS, which enable the characterization of their physicochemical properties. These findings provide an essential foundation for the understanding of the ternary cellulose-hemicellulose-polyphenol system and open up new perspectives for the development of smart functional materials derived from sustainable sources.

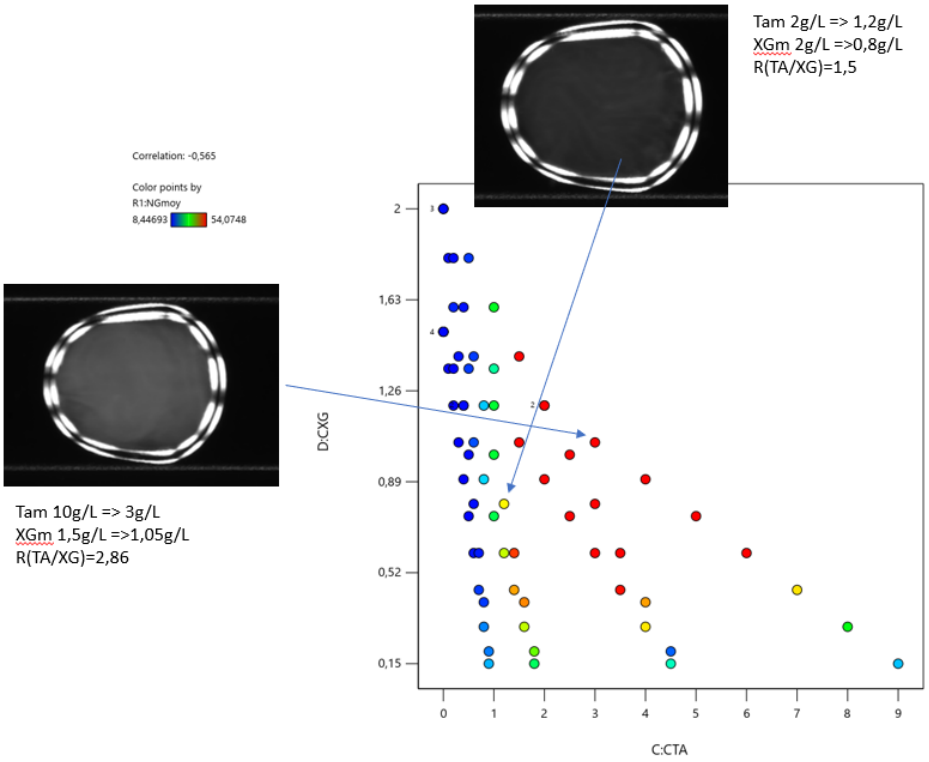

Figure 1. Phase diagram of Xyloglucan(XG) and Tannic acid(TA) in water expressed in mean grey level(NGmoy) of the inside of the droplets, red points represents high complexation (low NGmoy) and blue points represents low complexation (high NGmoy). Pictures of droplets at 2 phases representatives points are shown

O41.4 - SYNTHESIS AND CHARACTERIZATION OF POLYSACCHARIDE-BASED BLOCK COPOLYMERS OBTAINED BY CLICK POLYMERIZATION OF NEW MONOMERS DERIVED FROM β-CYCLODEXTRIN

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Synthesis and characterization of polysaccharide-based block copolymers obtained by click polymerization of new monomers derived from

β-cyclodextrin

Dindet S. E. Koffi Teki[a], Matthieu Pélingre[a], Cristel Yacovone[b], Adriana Kolender[b], Cédric Przybylski[c], Emmanuel Petit[d], Eric Drockenmuller[e], Véronique Bonnet[a], José Kovensky [a]*

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[b] Departamento de Química Orgánica, FCEyN, and Centro de Investigaciones en Hidratos de Carbono (CIHIDECAR-CONICET), Universidad de Buenos Aires, Argentina

[c] Université Paris-Saclay, Univ Evry, CY Cergy Paris Université, CNRS, LAMBE, 91025, Evry-Courcouronnes, France

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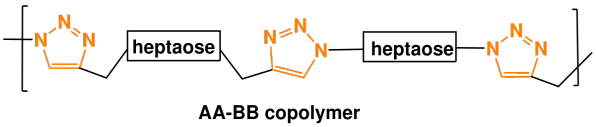
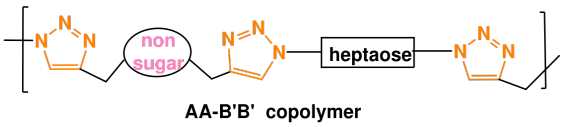
The synthesis of well-defined oligosaccharides via cyclodextrin (CD) ring opening is an efficient method for obtaining tailored monomers, suitable for further polymerization. In our previous work [1] we developed a new strategy to obtain differentially substituted heptaoligosaccharides from β-cyclodextrin leading to benzoylated maltoheptaoses substituted at the anomeric position with an azido (A) or a propargyl group (B) and leaving a free hydroxyl at the C-4 of the non-reducing unit. We present here: (i) the regioselective functionalization of the C-4^{VII} with a second group (azido or propargyl) in 81-96% yield, producing α,ω-diazidoheptaose, α,ω-dipropargylheptaose, and ω-azido-α-propargylheptaose (AA, BB, and AB monomers, respectively) and their deprotected versions with high purity (87-99%); (ii) the polymerization of the newly synthesized oligosaccharidic blocks via

copper-catalyzed 1,3-dipolar cycloaddition leading to original and distinct polymers (homo- and hetero-copolymers, hydrophobic/hydrophilic blocks); (iii) the copolymerization of the diazido AA monomer with two different dialkynes: 1,7-octadiyne and bispropargyl-PEG-5; (iv) the complete characterization of the polymers by SEC MALS, thermal analysis (TG and DSC), XRD, FTIR, NMR, and MALDI-TOF MS. Polymers of DP 1-34 (7 to 238 sugar units) were obtained in moderate to excellent yields (30-85%) [2]. In AA-BB polymers, the alternating insertion was confirmed by NMR and MALDI-TOF. The water-soluble poly(glyco-triazole) containing PEG units had M_n 20640 and M_w 39650, and preliminary experiments allowed to obtain spherical nanoparticles of about 200 nm (observed by SEM), a key starting point for potential applications.



AA-BB copolymer



AA-B'B' copolymer

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Parallel session 42 - Materials & Engineering

2025-08-28
13:50 - 14:50
Parallel session 42 - Materials & Engineering

O42.1 - Glycerol-plasticized, cellulose-based bioplastics with beeswax as innovative, biodegradable food packaging

Textile, Pulp, Paper & Packaging
Materials & Engineering

Glycerol-plasticized, Cellulose-Based Bioplastics with beeswax AS Innovative, Biodegradable food Packaging

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The world population has exceeded 8 billion and is expected to reach over 9.7 billion by 2050, increasing the demand of food packaging solutions. Food packaging plays an important role in preserving the nutritional quality and freshness of food during transport and storage. Conventional petroleum-based plastics have long dominated the food packaging industry. However, these materials contribute to resource depletion, environmental degradation and persistent plastic pollution. Among the different solutions, natural polysaccharides such as cellulose present a promising alternative.

In this work, we report the fabrication of transparent, biodegradable and high-barrier bioplastics from cellulose and glycerol and natural beeswax as functional additives by using a mixture of trifluoroacetic acid (TFA), trifluoroacetic anhydride (TFAA), and chloroform as solvents. First, the role of glycerol on the final properties of the plasticized cellulose-based bioplastics was systematically investigated and compared with other common food packaging materials. In particular, the incorporation of glycerol modified the mechanical properties by inducing a plasticizer effect, Figure 1A, affecting negatively to the barrier properties. Second, the effect of the addition of natural beeswax to the formulations was studied. Optical, chemical, structural, mechanical, thermal, and hydrodynamic properties were fully characterized. In addition, the biodegradability in seawater was investigated. The incorporation of beeswax ruled out the transparency and UV blocking, modified the main mechanical parameters, and improved the thermal stability and the antioxidant capacity, as well as the hydrodynamic and barrier properties. Furthermore, these cellulose-beeswax bioplastics were evaluated as viable food packaging materials by determination of the overall migration, oxygen permeability values at different relative humidities, measurement of antimicrobial activity against *Escherichia coli* and *Bacillus cereus*, and through preservation of fresh-cut pear slices, showing results similar to those obtained by using low-density polyethylene, Figure 1B.

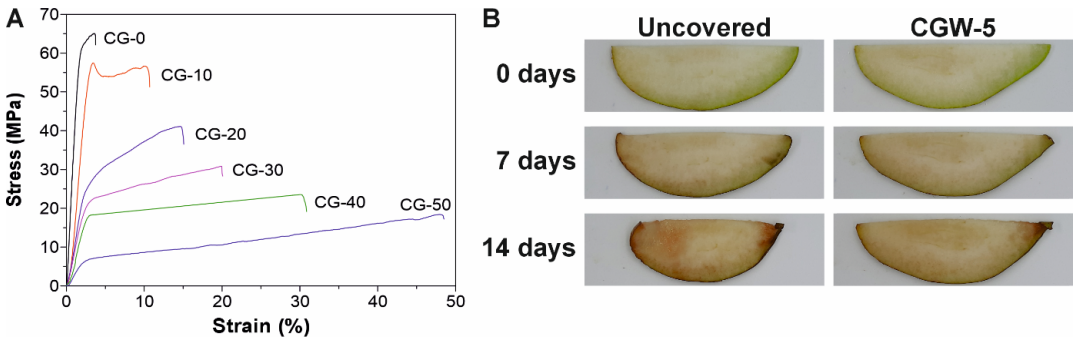

Figure 1. A, typical stress-strain curves of plasticized cellulose-glycerol (CG) films. samples were designated with the nomenclature CG-x, with "C" and "G" for cellulose and glycerol, respectively, and "x" for the weight percentage of glycerol. **B,** photographs of pear slices uncovered and covered with CGW-5 films after 0, 7, and 14 days. Samples were designated as CGW-x where "C" is for cellulose, "G" is for glycerol, "W" is for beeswax, and "x" indicates the weight percentage of beeswax.

O42.2 - PERACETIC ACID PRETREATMENT OF ASPLUND-REFINED SPRUCE: CHEMICAL ANALYSIS AND FIBER PERFORMANCE

Textile, Pulp, Paper & Packaging
Materials & Engineering

Peracetic Acid Pretreatment of Asplund-Refined Spruce: Chemical analysis and Fiber Performance

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Natural wood fibers have demonstrated excellent potential as sustainable alternatives to conventional reinforcement materials in composite applications. Their abundance, low density, and favorable mechanical properties make them suitable for use in biocomposites across industries such as automotive, packaging, and construction. A key advantage of natural fibers lies in their high content of polysaccharides, primarily cellulose and hemicellulose, which contribute to mechanical strength, flexibility, and bonding capability. Cellulose provides stiffness and tensile strength due to its crystalline structure, while hemicellulose enhances inter-fiber bonding and adhesion to matrix materials [1, 2]. However, challenges remain in processing natural fibers to achieve optimal bonding performance, fibrillation, and compatibility with biopolymeric matrices, while using low severity processes (e.g. low energy consumption) to ensure feasibility. One promising strategy is to combine mechanical pretreatment with green chemical pulping techniques to enhance fiber reactivity and accessibility. In this context, peracetic acid (PAA) is an environmentally friendly oxidative agent capable of selectively removing lignin while preserving cellulose and hemicellulose [3]. A key challenge in PAA pulping is ensuring efficient mass transfer of the solvent within intact wood chips and pieces to achieve complete pulping into individual fibers. This leads to the necessity of temperatures above 80°C or extended reaction times up to 3-25 hours [4–6]. To enhance the reaction rate, the accessible surface area of the chips can be increased through low-energy mechanical refining, such as the Asplund process, which preserves the structural integrity of the original fibers prior to chemical treatment [7]. Further investigations are necessary to clarify how varying PAA pulping conditions specifically affect the chemical composition, mechanical integrity, and morphological characteristics of mechanically pre-refined fibers.

This study investigates the influence of different PAA pulping conditions on Asplund-refined fibers from Norway spruce (*Picea abies*). Pulping was carried out at temperatures of 70°C and 80°C, with reaction times of 60 and 120 minutes. The obtained fibers were then compared to holocellulose fibers obtained through a standalone PAA pulping. Both chemical and mechanical properties were analyzed to investigate the effects of the pulping parameters on the lignocellulosic composition and overall fiber performance. For mechanical evaluation, paper sheets were formed and tested for inter-fiber bonding strength using tensile testing, and individual fiber strength was determined through zero-span tensile tests. Basic morphological properties such as fiber length, width, and curl index were assessed using a fiber analyzer, while fiber crystallinity was measured via X-ray diffraction (WAXD). Chemical analysis included determination of Klason lignin content and quantification of carbohydrate composition. Results revealed that oxidizing and preserving the polysaccharide fraction through selective delignification with PAA not only aligns with green chemistry principles but also enhances the fibers' reinforcement potential in biocomposites, thereby offering promising outcomes for sustainable material applications.

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O42.3 - The sorption behaviour of anionic dyes on cationised cellulose fibres

Textile, Pulp, Paper & Packaging
Materials & Engineering

The sorption Behaviour of anionic dyes on cationised cellulose fibres

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Cationisation and salt-free reactive dyeing of cellulose fibres offer a promising alternative for cotton textile colouration, providing benefits such as reduced salt usage, higher dye exhaustion rates, and less coloured wastewater. However, its industrial application remains limited due to inconsistent dyeing outcomes, such as uneven colouration and a lack of predictability in results. This requires a better understanding of the interplay between the degree of cationisation (introduced during cationisation) and the inherent carboxyl groups on the fibre, and how that affect the sorption process.

In our work (reference + unpublished results), cellulose fibres were cationised using 3-chloro-2-hydroxypropyl-*N*,*N*,*N*-trimethylammonium chloride (CHPTAC), achieving cationic group contents between 12 and 185 mmol kg^{-1}. Significant changes in dye uptake behaviour were observed when cationisation levels exceeded the inherent carboxyl content of fibres, as observed through monitoring of the zeta potential and dye sorption measurements. Dye sorption on non-cationised fibres typically exhibits Freundlich isotherm relationships, but when cationic groups are introduced, the sorption behaviour changes to a combination of a Langmuir and Freundlich isotherm. The point of transition from a Langmuir to Freundlich isotherm changes with the level of cationisation and also with molecular structure of the dyes. The results provide fundamental insights that will help improve predictability of dyeing processes and contribute to commercial uptake of cellulose cationisation as a means to mitigate the environmental impact of dyeing processes.

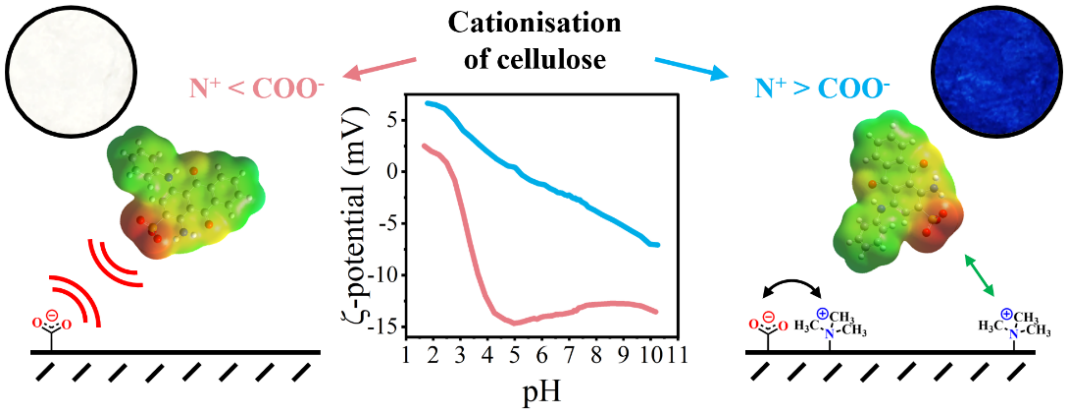

Figure 1. A substantial change in electrokinetic behaviour and an increase in dye sorption occurs when the cationic group content exceeds the carboxyl group content of the fibre.

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Poster

Poster session, exhibition and mingle at Tonhallen.

2025-08-26
17:40 - 20:00
Poster session, exhibition and mingle at Tonhallen.

B1 - IMPACT OF MOLECULAR WEIGHT OF SCHIZOPHYLLAN ON ITS BIOLOGICAL ACTIVITY AND MODIFICATIONS

Drug Delivery Systems
Biomedical & Well-being Applications

IMPACT of molecular weight of schizophyllan on its biological activity and modifications

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Schizophyllan (SPG), a β-Glucan from the fungus *Schizophyllum commune* (Figure 1) exhibits notable biological activity, having strong immunomodulatory and anticancer properties. The biological effects of SPG are deemed to be related to its triple-helical structure and molecular weight (expressed by weight-average molecular weight, M_w), with single-strand SPG with $M_w < 50$ kDa being inactive [1]. However, the high molecular weight of native SPG and its often broad molecular weight distribution hinder its solubility in aqueous media and limit its utility in a pharmaceutical context [2].

Here, the impact of M_w of SPG on its properties and biological activity was investigated in detail. Initially, the wet-jet milling technique was employed to reduce both the M_w and dispersity of SPG, thereby enhancing water solubility and improving uniformity. Next, SPG samples with different M_w (between 4500 kDa and 250 kDa) were characterised, and their biological properties, including their affinity for different cell membrane receptors, were evaluated. Contrary to expectations, the biological activity did not uniformly decrease with M_w, indicating that some of the lower molecular weight fractions might have an interesting potential for biomedical applications and further modifications, while others ($M_w \sim 250$ kDa) showed a sharp decrease in activity.

Moreover, oxidative modifications of the best candidates were performed, the reaction was optimised, and their properties were evaluated. Results show that SPG with M_w as low as 300 kDa can be used to prepare interesting biologically active derivatives.

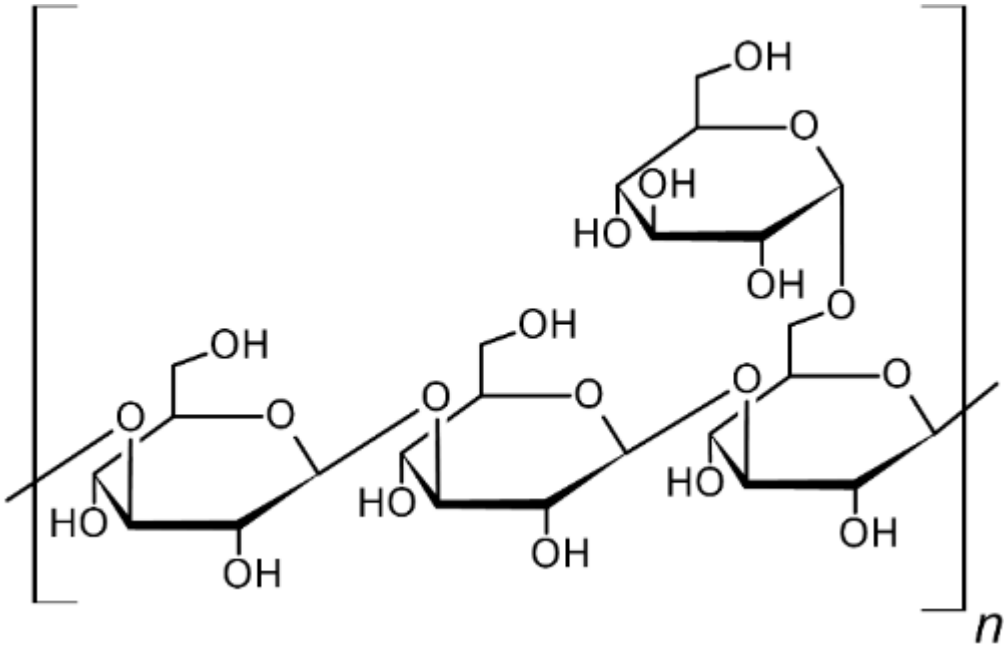

Figure 1. Structure of schizophyllan.

Acknowledgements: *The authors thank the Ministry of Education, Youth and Sports of the Czech Republic – DKRVO RP/CPS/2024-28/001, the Ministry of Health of the Czech Republic – AZV NW24-03-00331 and the Internal Grant Agency of Centre of Polymer Systems in Zlín – IGA/CPS/2025/001 for financial support.*

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B2 - ECO-FRIENDLY SURFACE ACTIVATION OF SILICONE FOR CHITOSAN-BASED ANTIMICROBIAL COATINGS IN MEDICAL DEVICES

Biomedical Devices
Biomedical & Well-being Applications

Eco-Friendly Surface Activation of Silicone for Chitosan-Based Antimicrobial Coatings in Medical Devices

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Silicone-based materials are extensively used in medical devices due to their flexibility and biocompatibility. However, their inherent susceptibility to microbial adhesion and biofilm formation presents a critical risk in clinical environments [1]. In this study, we developed a green method for silicone surface activation using mild amine-based reagents in eco-friendly solvents. For this purpose, silicone discs were activated by various amine-based compounds prepared in eco-friendly solvents such as water and isopropanol. Surface amine group density was quantified using a ninhydrin assay, which was also employed to monitor the stability of amine groups on the silicone surface over a 10-day period. Chitosan was then used to coat the activated silicone via glutaraldehyde crosslinking, and the attachment was confirmed through FTIR analysis and additional amine quantification. The antibacterial activity of the coated samples was evaluated against various Gram-positive and Gram-negative bacteria using the drop plate method.

The results demonstrated that the ethanolamine in isopropanol provided the most favorable balance between effective surface modification (303 ± 31 nmol/cm^2) and preservation of mechanical integrity. Chitosan was successfully grafted onto ethanolamine-activated silicone via glutaraldehyde crosslinking, with FTIR and surface amine measurements confirming stable attachment. Antibacterial testing revealed that chitosan-coated silicone significantly reduced bacterial load across all tested strains, with *Enterococcus faecalis* CFUs decreasing from 7.1 to 3.7 Log_{10} CFU/mL (Figure 1). Mechanical testing confirmed that the surface modifications and chitosan coating did not compromise the flexibility or tensile strength of the silicone. This green chemistry-based approach offers a non-toxic alternative to conventional surface modification techniques, making it a promising strategy for developing antimicrobial medical devices with enhanced safety and performance.

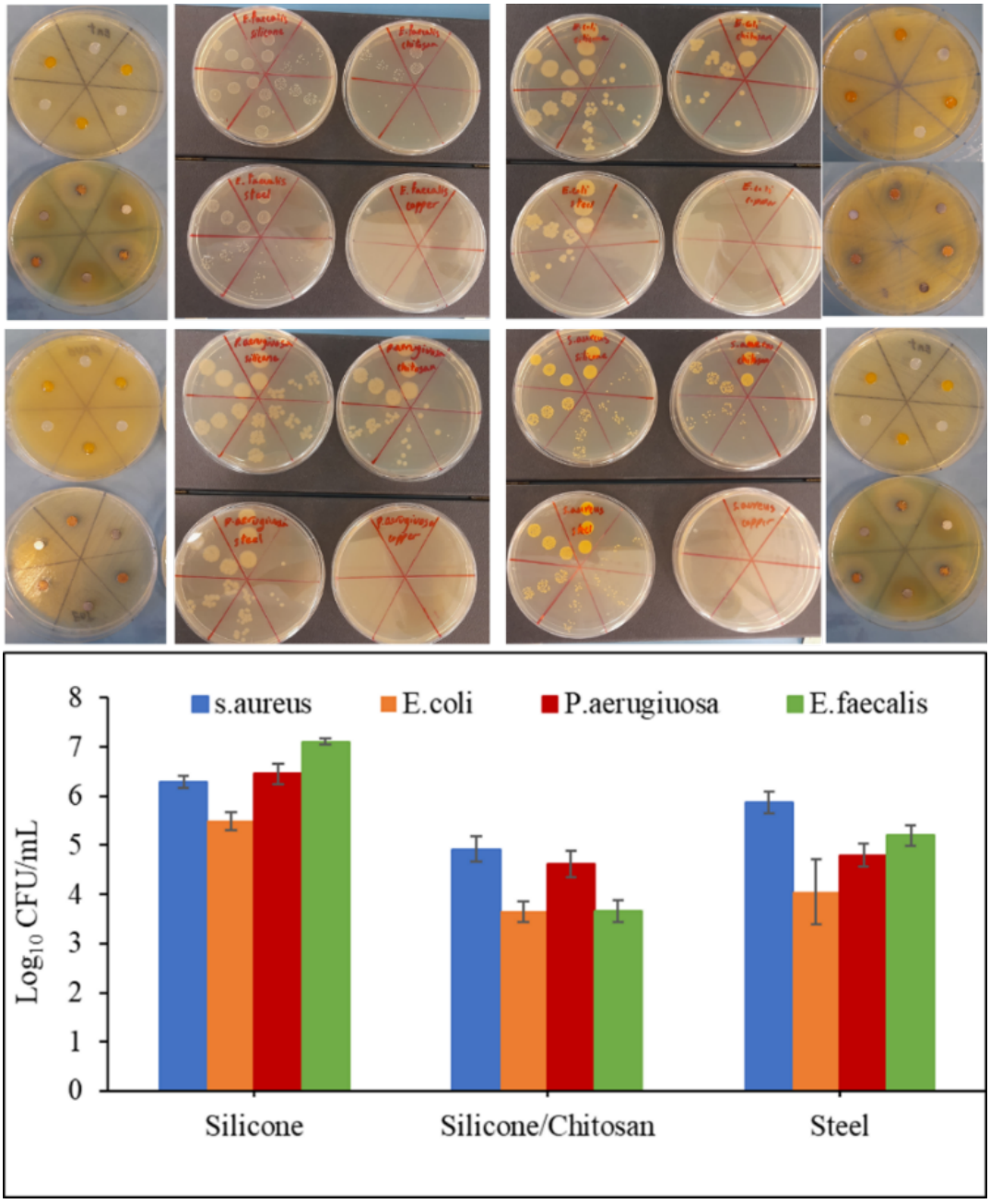

Figure 1. Bacterial density expressed as log CFU mL^{-1} of various bacteria, after 18 h of incubation with silicon, silicon/chitosan and steel surfaces.

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B3 - EXTRACTION AND CATIONIZATION OF ACACIA LIGNIN FOR SUSTAINABLE HAIR CONDITIONERS

Cosmetics & Skincare
Biomedical & Well-being Applications

EXTRACTION AND CATIONIZATION OF ACACIA LIGNIN FOR SUSTAINABLE HAIR CONDITIONERS

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The growing popularity of cosmetic products has sparked increasing concern over their environmental footprint. Many conventional hair care ingredients—particularly cationic conditioning agents—are known to pose risks to aquatic ecosystems [1]. In response, the cosmetic industry is turning to renewable, eco-friendly alternatives. Among these, lignin—a natural compound derived from biomass—stands out as a promising candidate. Abundant, biodegradable, and low in toxicity, lignin offers exceptional potential as a sustainable ingredient for future formulations [2]. While native lignin can be used in some contexts, its application in hair conditioners requires further modification. Since positively charged polymers are essential for neutralizing the negatively charged hair surface and controlling frizz, cationizing lignin emerges as a smart and innovative strategy. This approach not only enhances lignin's compatibility with hair fiber chemistry but also paves the way for greener, more responsible hair care solutions.

In this work, lignin was extracted from acacia wood [3] and chemically modified to produce cationic derivatives capable of interacting with damaged human hair. Cationization was achieved through reaction with 2,3-epoxypropyltrimethylammonium chloride, and the reaction conditions—specifically the lignin-to-cationizing agent ratio and temperature—were optimized using a design of experiments to maximize the degree of substitution and zeta potential. The resulting derivatives were thoroughly characterized (including their ecotoxicity) and compared to a commercial cationic polymer (PQ11) widely used in cosmetics. Finally, basic hair conditioner formulations incorporating either the novel lignin derivatives or PQ11 were developed and evaluated for their stability,

viscosity, and sensory properties.

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B4 - PEPTIDE-FUNCTIONALIZED PULLULAN HYDROGELS FOR THE REGENERATION OF RETINAL PROGENITOR CELLS

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

Peptide-functionalized pullulan hydrogels for the regeneration of retinal progenitor cells

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As the global ageing population increases, the number of patients affected by age-related eye diseases like glaucoma is escalating. These conditions cause progressive damage to retinal ganglion cells (RGCs), crucial for transmitting visual stimuli to the brain, resulting in vision loss. To regenerate these RGCs, stem cell therapies for ocular regenerative medicine have emerged. These therapies involve extracting patient-derived cells, reprogramming them into stem cells, and differentiating them into retinal progenitor cells (RPCs) or RGCs [1].

Effective cell differentiation requires a biocompatible biomaterial that mimics the native tissue and supports cell attachment. Matrigel, a widely used support material derived from Engelbreth-Holm-Swarm mouse tumours, has been proven effective in promoting cell proliferation and differentiation. However, ethical concerns, low productivity, batch-to-batch variability, and high costs increase the need for more reliable and tuneable alternatives [2].

In this study, multifunctional pullulan hydrogel coatings are developed to replace Matrigel. First, pullulan is carboxymethylated to obtain carboxymethyl pullulan (CMP) with a degree of substitution up to 1.00. Methacrylate groups are then introduced onto the pullulan backbone, followed by functionalization with the RGDS cell adhesion peptide using EDC/NHS chemistry. Spin-coated hydrogel materials are prepared and UV-irradiated to create radial directionality. The presence of carboxymethyl, methacrylate and RGDS groups is confirmed via FTIR, NMR (^{1}H-NMR, ^{13}C-NMR) and XPS analysis, and the mechanical properties are determined by rheological testing. Furthermore, the cell adhesion of stem cells and differentiated retinal progenitor cells on the hydrogel materials is studied, demonstrating the potential of RGDS-functionalized pullulan hydrogel scaffolds for ocular regenerative therapies.

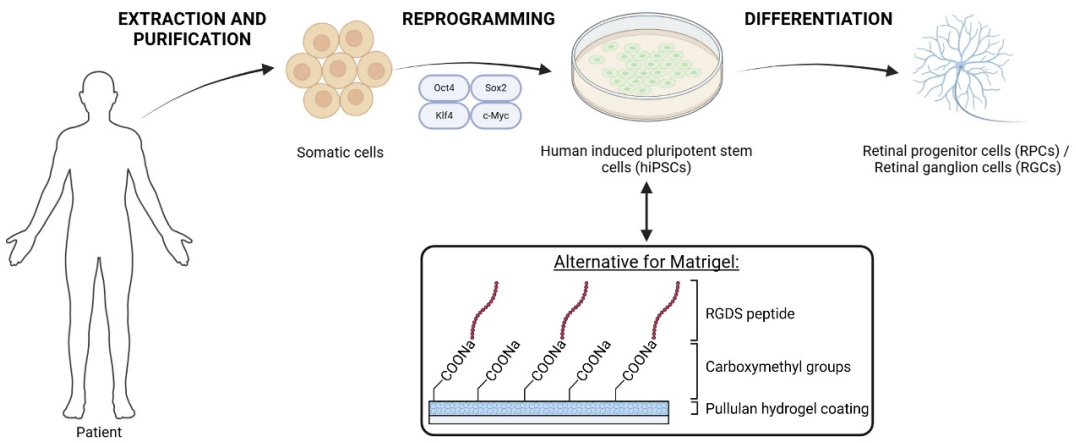

Figure 1. Schematic representation of stem cell-based retinal cell generation using a functionalized pullulan hydrogel coating to replace Matrigel.

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B5 - INJECTABLE COMPOSITE HYDROGEL FOR WOUND HEALING APPLICATIONS

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

Injectable Composite Hydrogel for WOUND HEALING Applications

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Injectable hydrogels are gaining prominence in biomedicine for applications such as tissue regeneration and wound healing [1]. Chitosan is a widely used biopolymer, but its poor solubility at physiological pH often necessitates chemical modifications that can introduce concerns about non-physiological degradation products [2].

This study reports the development of novel injectable, self-healing, and anti-inflammatory composite hydrogels for tissue regeneration and wound healing, addressing the solubility limitations of chitosan. Water-soluble half-acetylated chitosan (SCN), synthesized by reacetylating chitosan to a degree of deacetylation (DD) of ~55% to ensure solubility at physiological pH without artificial functional groups, formed the hydrogel matrix. Dialdehyde cellulose (DAC), prepared via periodate oxidation of cellulose, was employed as a biocompatible crosslinker, uniquely binding SCN through dynamic Schiff base linkages and anchoring polypyrrole (PPy) nanoparticles via aldol condensation. PPy was incorporated for its established biocompatibility and therapeutic properties, including anti-inflammatory and wound healing-accelerating effects [3]. Hydrogels, also containing 5 wt% PPy colloids, were fabricated under mild conditions by mixing SCN and DAC solutions. Rheological analyses confirmed their injectable nature, characterized by shear-thinning behavior and rapid self-healing capabilities crucial for minimally invasive delivery. All formulations demonstrated excellent cytocompatibility with NIH/3T3 fibroblasts and RAW 264.7 macrophages. Notably, PPy-containing hydrogels significantly accelerated fibroblast migration in vitro, achieving up to two-fold faster wound closure compared to controls, indicating substantial wound healing promotion. Furthermore, these SCN-DAC-PPy hydrogels markedly reduced the production of pro-inflammatory mediators, nitric oxide (NO) and interleukin-6 (IL-6), by LPS-stimulated macrophages, highlighting their potent anti-inflammatory activity. Consequently, these composite hydrogels, with their combined injectability, self-healing capacity, biocompatibility, and immunomodulatory effects, hold significant promise as advanced biomaterials for wound care and tissue regeneration.

Acknowledgement: This work was supported by the Czech Science Foundation grant no. 24-11534S and by the Ministry of Education, Youth and Sports of the Czech Republic – DKRVO (RP/CPS/2024-28/001).

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B6 - ESTERIFICATION OF CHITOSAN FOR IMPROVED THERMAL PROPERTIES IN NANOIMPRINT LITHOGRAPHY APPLICATIONS

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

Esterification of Chitosan for Improved Thermal Properties in Nanoimprint Lithography Applications

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Topographical features on biomaterial surfaces significantly influence cellular behaviors, such as adhesion, proliferation, and differentiation [1]. Chitosan, a natural polysaccharide known for its biocompatibility and biodegradability, holds great promise for various biomaterial applications [2]. However, to enhance its suitability for advanced processing methods, modifications are often necessary.

In this study, we focused on tailoring chitosan's thermal properties for nanoimprint lithography (NIL), a high-resolution patterning technique [3]. Chitosan was esterified to reduce its glass transition and melting temperature, improving its processability in NIL. Characterization using Fourier-transform infrared spectroscopy (FTIR) and nuclear magnetic resonance (NMR) confirmed the successful esterification, while thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) demonstrated a significant reduction in the polymer's melting point, indicating improved thermal properties. The esterified chitosan was subsequently used to create thin films and form various topographical features via NIL.

This work highlights the successful development of thermally tunable chitosan esters for nanoimprinting. By combining the inherent advantages of polysaccharide esters with the precision of NIL to generate distinct topographical features, this system offers a versatile platform for studying biointerfaces. It is ideally suited for exploring the interactions between surface topography, protein adsorption, and cell-surface behavior, providing valuable insights for biomaterial design and tissue engineering applications.

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B7 - ENZYME-DRIVEN CROSSLINKING OF 3D-PRINTED BIOSACCHARIDE HYDROGELS FOR ENHANCED TISSUE ENGINEERING SCAFFOLDS

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

Enzyme-Driven Crosslinking of 3D-Printed Biosaccharide Hydrogels for Enhanced Tissue Engineering Scaffolds

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The incorporation of biopolymers in 3D printing, particularly biosaccharide-based hydrogels, has significantly advanced tissue engineering and regenerative medicine[1,2]. This study focuses on the development and characterization of 3D-printed biomaterials using alginate (Alg) modified to alginate-tyramide (Alg-TA), nanofibrillated cellulose (NFC), glucose, calcium carbonate ($CaCO_3$), and the enzymes glucose oxidase (GOx) and horseradish peroxidase (HRP). By employing a dual-enzyme system, solution-free crosslinking is achieved through a combination of ionic and covalent mechanisms-H_2O_2 generated in situ facilitates covalent crosslinking, while $CaCO_3$ enables ionic crosslinking. The resulting scaffolds exhibit a tensile strength of 0.13 ± 0.02 N/mm² and an elongation at break of 77 ± 4 %, whereas those without CaCO3 demonstrate higher tensile strength (0.26 ± 0.04 N/mm²) but reduced flexibility (36 ± 3 %). These structures exhibit excellent shape fidelity, mechanical integrity, and dimensional stability. A detailed analysis of crosslinking parameters, such as pH, glucose and enzyme concentrations, and atmospheric conditions, reveals a complex interplay influencing scaffold formation. The developed bioinks present a promising avenue for fabricating strong, adaptable, and biocompatible 3D-printed scaffolds tailored for regenerative medicine applications.

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B8 - ANISOTROPIC CHITIN-BASED HYDROGELS FOR BONE-MIMETIC CELLULAR GUIDANCE

Tissue Engineering Scaffolds
Biomedical & Well-being Applications

Anisotropic chitin-based hydrogels for Bone-mimetic cellular guidance

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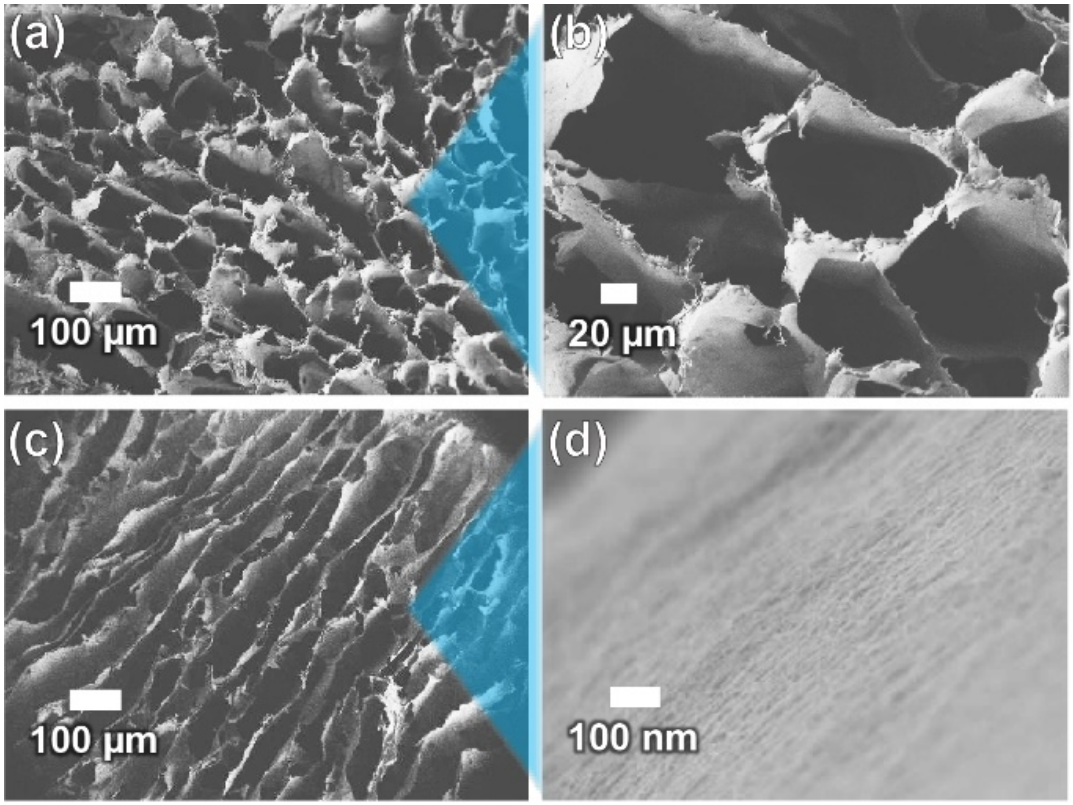
Guiding cell growth through structural cues is central to next-generation biomaterials. Inspired by the hierarchical organization found in nature, we developed nanochitin based anisotropic hydrogels by leveraging strong amine-polyphosphate crosslinking [1,2]. The non-covalent amine-phosphate interactions, commonly found in biological systems, ensued the hydrogel networks with remarkable stability in aqueous environment.

We employed unidirectional freeze-casting followed by thawing in a crosslinking solution: an approach increasingly recognized for engineering directional porosity in biomaterials to induce nanoscale to microscale alignment [3,4]. The alignment of the pores and the fibre of the pore wall were validated via SEM (Figure 1) and X-ray scattering. The pore dimensions were then optimized by tuning freezing conditions to improve the mass transfer.



Biological in vitro evaluation with pre-osteoblastic cells showed that the hydrogels supported cell growth and adhesion which are key indicators of bone tissue integration [5]. Such an anisotropic hydrogel architecture exhibited cellular guidance similar to behaviour seen with high-order structural biomaterials.

Figure 1. SEM images of the fabricated hydrogels. (a) and (b) show the microscale alignment of the pores in the transverse direction, while (c) and (d) display the microscale alignment of the pore channels and the fibre alignment within the pore walls in the longitudinal direction, respectively.

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B9 - Nanocomposite of quaternized starch and cellulose nanofibrils with OncoA-loaded hollow silica nanospheres for controlled release and cancer therapy

Drug Delivery Systems
Biomedical & Well-being Applications

Nanocomposite of quaternized starch and cellulose nanofibrils with OncoA-loaded hollow silica nanospheres for controlled release and cancer therapy

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Nanostructured porous composites were fabricated *via* freeze-drying, using a polymeric matrix composed of cellulose nanofibrils from *Calotropis procera* (NFCCp) and quaternized starch from *Spondias purpurea* L. (QCS), crosslinked with N,N'-methylenebisacrylamide. These composites incorporated hollow mesoporous silica nanospheres (HMSN) loaded with oncocalyxone A (HMSN@OncoA), achieving an encapsulation efficiency of 26.07%. The initial components of the polymeric matrix were derived from low value-added biomass obtained from the aforementioned plant species and were chemically modified to form a network through electrostatic interactions and crosslinking bonds [1]. The silica-based nanocarrier exhibited a high surface area and nanoscale dimensions, including both mesopores and micropores. Cytotoxicity studies with OncoA and HMSN@OncoA showed activity against leukemia (HL-60) and colorectal cancer (HCT-116) cell lines, with no observable *in vivo* toxicity in the zebrafish model. The porous composites (PC-HMSN@OncoA) exhibited porosities ranging from 19.8% to 25.6%, with irregular morphology and heterogeneous pore sizes and shapes. Crosslinking was confirmed by solid-state NMR, with graphitization degrees ranging from 12.31% to 24.12%. The release kinetics of PC-HMSN@OncoA followed a non-Fickian diffusion mechanism and Case II transport, mainly governed by sorption, swelling, and relaxation of the polymeric matrix [2]. These preliminary results suggest that the nanostructured composites incorporating HMSN@OncoA may serve as effective platforms for drug loading and localized release of anticancer agents, while also supporting cell growth and tissue regeneration.

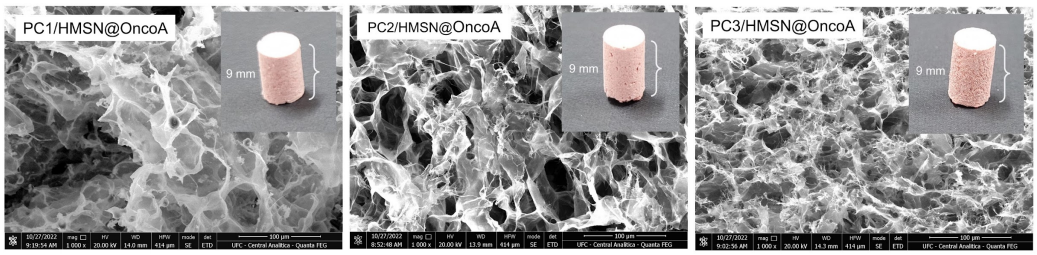

Figure 1. Micrographs of PC1 to PC3 composites containing HMSN@OncoA.

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B10 - Colloidal Stability of Nanocellulose Hydrogels in Biological Media

Other
Biomedical & Well-being Applications

Colloidal stability of nanocellulose hydrogels

in biological media

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Biomaterials are fundamental to the healthcare and biomedical industry, forming the foundation of medical devices, therapeutic products, tissue engineering, and cell culture research. As the field shifts toward sustainable, natural, and animal-free alternatives, plant-derived hydrogels—especially nanocellulose—are gaining attention. This shift is driven by ethical considerations, regulatory changes, and a growing need for consistent and reproducible materials.

Nanocellulose-based biomaterials have shown strong potential as cell culture matrices influencing cell behavior, proliferation, and tissue formation. Their viscoelastic properties and fibril structure enable them to mimic the extracellular matrix (ECM), supporting a range of biomedical applications. Additionally, nanocellulose offer a renewable and cost-effective alternative to traditional culture materials.

Despite these advantages, nanocellulose-based materials face challenges due to variability in fibril dimensions and the tendency of aggregation, which may limit their applicability. In biological settings, nanocellulose colloidal hydrogels must interact with physiological media that support cell viability, growth, and function, including phosphate-buffered saline (PBS), saline solution (0.9 wt% NaCl), Dulbecco's Modified Eagle Medium (DMEM), and supplement systems such as fetal bovine serum (FBS). These media can influence the stability of nanocellulose, directly affecting their performance in biological environments.

However, studies on the interactions between nanocellulose hydrogels and biologically relevant media remain limited. In this study, we evaluated the colloidal and rheological stability of native nanofibrillated cellulose (nNFC) and anionic TEMPO-oxidized nanofibrillated cellulose (aNFC) dispersions using turbidity, sedimentation, zeta potential, conductivity, and rheological properties.

In salt-containing media such as PBS and saline, both nNFC and aNFC formed gel-like structures through ionic interactions. Salt increased viscosity, with aNFC forming stronger and more stable gel, while nNFC formed a weaker network. Electrostatic screening reduced fibril repulsion, promoting partial flocculation driven by van der Waals and electrostatic attractions. Both dispersions remained

stable over 24 hours, with only a slight clarification (~2 mm), indicating good gel integrity with minimal phase separation—favorable characteristics for applications requiring increased gel strength.

In DMEM, nNFC formed a weak gel with moderate viscosity, while aNFC created a highly viscous, stable structure. When supplemented with FBS, interactions between serum proteins and nanocellulose slightly reduced viscosity. aNFC exhibited stability, forming a moderately strong gel that retained its performance under typical culture conditions.

Understanding how nanocellulose interacts with physiological media is essential to optimizing its use in biomedical applications, as they may lead to structural changes that affect hydrogel performance. These findings contribute to the development of reliable nanocellulose-based materials, enabling the maximization of their potential in life sciences and biomedical applications.

B11 - Alginate Hydrogels: a Tunable Tool for Biotech Applications

Biomedical Devices
Biomedical & Well-being Applications

Alginate hydrogels: a tunable tool for biotech applications

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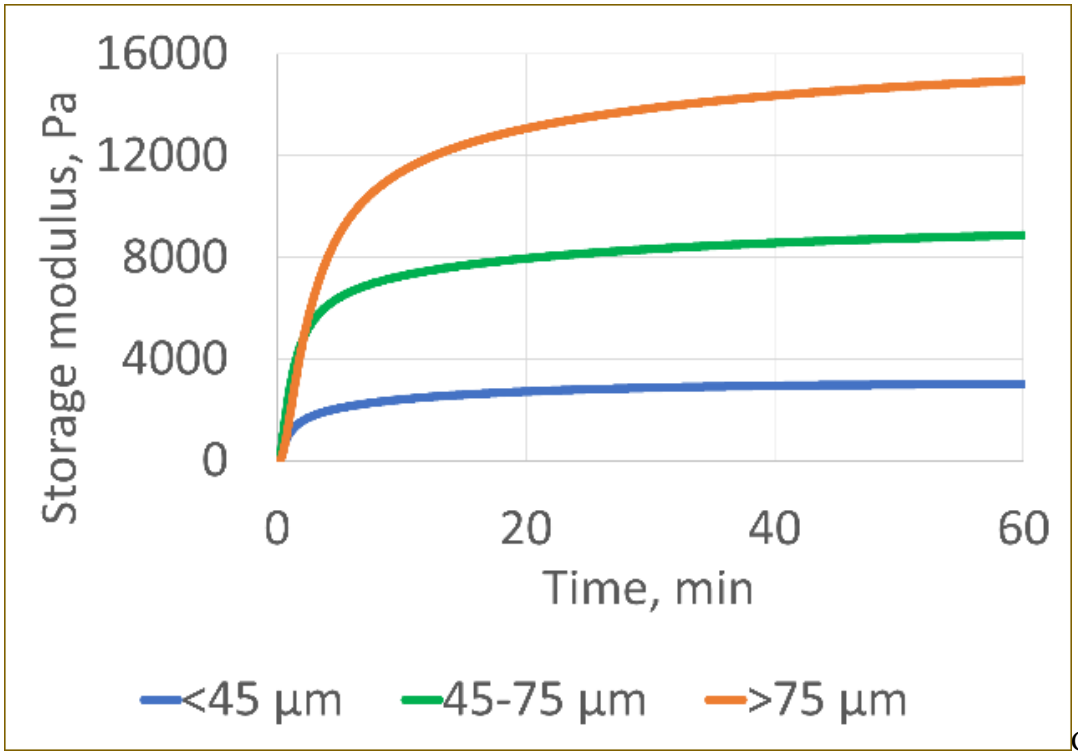
Alginates are biodegradable, non-toxic anionic polysaccharides derived from various species of brown seaweed. These linear polymers consist of repeating units of β-1,4-linked D-mannuronic acid (M) and α-1,4-linked L-guluronic acid (G) in varying proportions. Negatively charged alginates exhibit a high affinity for divalent cations such as Ca^{2+}, which specifically bind to the G blocks of the polymer to form hydrogels. There are two primary methods for preparing alginate gel: external and internal gelling. External gelling involves the diffusion of soluble Ca^{2+} ions into the alginate network, which can result in varying degrees of heterogeneity in the formed gel. Internal gelling involves incorporating an insoluble Ca^{2+} source (e.g., calcium carbonate, calcium sulfate) into the alginate polymer chains, which is then solubilized within the alginate network. This method ensures a more uniform distribution of cations and consistent gel strength throughout the alginate network. However, solubilization of these salts requires lowering the pH, which necessitates the addition of acid, which in some cases can cause an introduction of undesirable materials into the gel.

NovaMatrix's developed product PRONOVA® UP Ca M (calcium alginate salt) paves the way for self-gelling alginate systems that do not require additional gelling or solubilizing agents. The alginate "self-gel" system comprises two components: a sodium alginate solution and a calcium alginate suspension. When these components are mixed, gelation occurs through the diffusion of calcium cations between the two alginate fractions. The properties of calcium and sodium alginates (e.g., molecular weight, M/G ratio, viscosity, particle size) significantly influence the gelation kinetics and final gel properties. The specific arrangement and length of M-, G-, and M/G-blocks, along with the polymer's molecular weight, depend on the alginate source. Therefore, it is necessary to identify variable characteristics that are independent of the alginate source, which should enable tuning of the final gel properties and gel kinetics to meet the specific requirements of the gel, depending on its intended application.



Gel kinetics and elasticity of self-gelling alginate system can be controlled by sodium alginate viscosity as well as the size of calcium alginate fractions. Size of calcium alginate particle has more powerful influence on the final gel elasticity (**Figure 1**). Variations in this product property allow for a coarser tuning of the final properties of the gel.

The combination of different calcium alginate sieve fractions with varying sodium alginate viscosities enables the formation of gels with a wide range of firmness, from firmer to softer gels. This approach minimizes the influence of the alginate source alone on the final gel characteristics. The high variability in gel properties makes this system suitable for diverse applications, including tissue engineering, surgical sealing, cell encapsulation etc.

Figure 1. Influence of calcium alginate particle size on gel elasticity (sodium alginate with a viscositiy of 48 mPas).

B12 - Electrospinning Janus Scaffold Functionalized with Collagen-Mimetic Peptides for Advanced Tissue Engineering

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Electrospinning Janus Scaffold Functionalized with Collagen-Mimetic Peptides for Advanced Tissue Engineering

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Electrospinning is an essential technique in tissue engineering, capable of producing ultrafine fibers with a high surface area-to-volume ratio using simple and low-cost equipment. Bacterial cellulose (BC) stands out as a biopolymer due to its biocompatibility, lack of immunogenicity, and structural similarity to collagen in the extracellular matrix (ECM). Its large surface area and hydroxyl groups promote interactions with biomolecules, providing bioactive properties. Cellulose acetate (CA), obtained by partial or total acetylation of cellulose, presents distinct physicochemical properties such as high solubility in organic solvents, transparency, biodegradability, and mechanical strength. These characteristics facilitate its use in electrospinning and allow precise fiber control. Our study aims to develop a Janus-type scaffold composed of BC functionalized with a type I collagen-mimetic peptide on the hydrophilic side, and an electrospun CA layer forming the hydrophobic side. This dual-surface design is intended to simultaneously promote cell adhesion and inhibit microbial growth. Peptide synthesis was performed in solid phase (SPFS) using the Fmoc protocol with Rink amide resin. Purification was achieved through high-performance liquid chromatography (HPLC), revealing a major peak characteristic of the peptide. Functionalization was confirmed by ATR-FTIR spectroscopy, showing characteristic bands of amides I, II, and III. Scanning electron microscopy revealed BC fibrils associated with collagen I, as well as a thin and uniform film derived from the CMC used in the incorporation process. The next steps of the study involve electrospinning the material, followed by physicochemical and biological characterizations to assess its potential performance in biomedical applications.

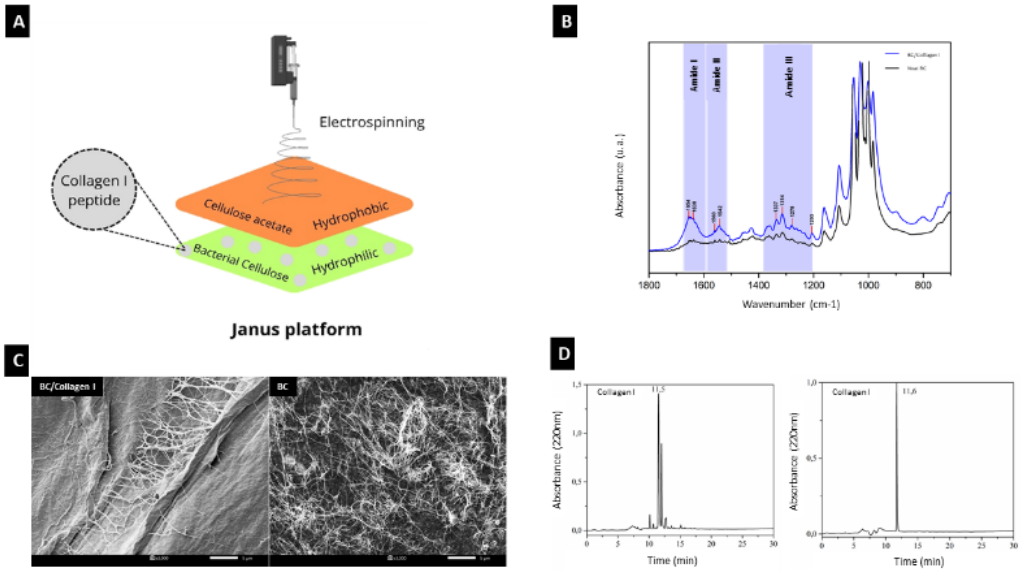

Figure 1: A) Graphical summary of the project; B) ATR-FTIR absorption spectra; C) Scanning electroning microscopy of the BC/Collagen I and native BC sample; D) Chromatographic profile before and after peptide purification.

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C1 - Microemulsions based on pulp industry residual products

Other
Chemistry, Biology & Physics

Microemulsions based on

pulp industry Residual products

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Microemulsions, unlike regular emulsions, are thermodynamically stable systems consisting of a surfactant and at least two immiscible liquids (e.g. oil and water) that are optically transparent and have unique properties, e.g. high solvation capacity for both polar and non-polar liquids [1][2]. One liquid is distributed, often in droplet form, in the other (see Figure 1), but bi-continuous structures can also be formed. Emulsions (including nanoemulsions) are kinetically but not thermodynamically stable, often created by means of intense mechanical shear, while microemulsions can be created spontaneously. The local pulp industry produces several residual products, such as turpentine and betulin, which have limited applications currently, yet have several exciting properties, including anti-microbial and anti-fungal activities.

One aim of this project is to assess whether turpentine is suitable as the oil phase in microemulsions, and under what conditions. Another aim is to use betulin as the active ingredient, once a stable turpentine microemulsion is created. The ultimate goal is to create microemulsions with anti-microbial and anti-fungal properties suitable for impregnating wood.

Currently, wood is impregnated under high pressure and temperature, to enable liquid penetration into the wood pore structure [4]. This is costly, energy-intensive and risky. Microemulsions can penetrate the pore structure of wood, without elevated pressure and temperature, if they have a suitable droplet size and surface tension.

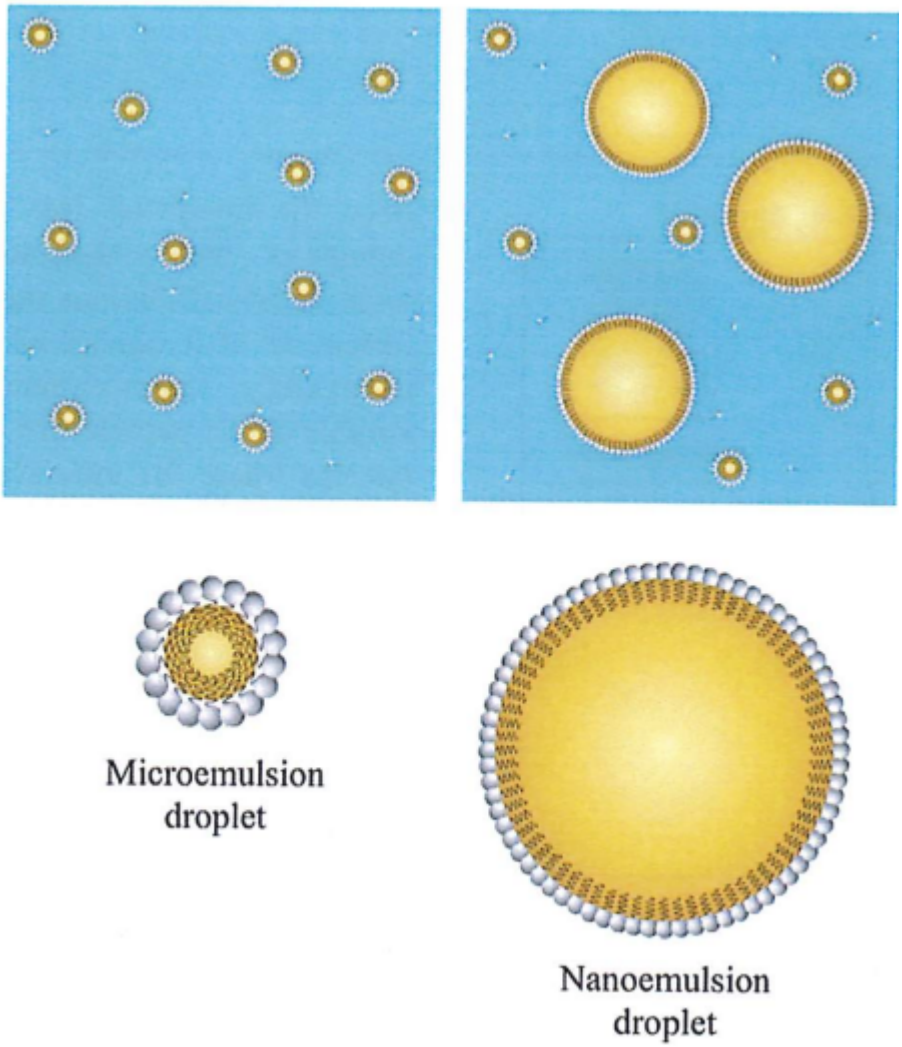

Figure 1. Schematic diagram of microemulsions and nanoemulsions made up of oil, water and surfactants, showing the similarity between the different particles – a hydrophobic core of oil and surfactant tails, as well as the hydrophilic shell of surfactant head groups [3].

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C2 - MINERALIZATION of CELLULOSE USING CO2: DISSOLUTION, GELATION and CARBONATION ASSESSMENTS

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

mineralization of cellulose using CO_2:

dissolution, gelation and carbonation assessments

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In typical invertebrates such as corals [1], mollusks [2], and echinoderms [3], carbonates are the predominant inorganic materials used in biomineral synthesis. The inherent brittleness of carbonates, particularly calcium carbonate ($CaCO_3$), is mitigated through their combination with biopolymers, including proteins and polysaccharides, via the process of biomineralization [4,5]. Dissolved CO_2 in seawater is converted into bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions, which then interact with mineral ions under the guidance of biopolymers, primarily through templated mineralization mechanisms [6]. While biological mineralization always takes months or even years [7], our innovative approach, cellulose mineralization, engineers CO_2 capture and accelerates synthetic mineralization in days and even hours as a practical and durable carbon sequestration method. The abundance of cellulose makes this strategy highly promising for a wide range of applications.

In this study, cellulose pulp was dissolved in a NaOH-based solvent, and the obtained cellulose dispersion was mixed with $Ca(OH)_2$. The mixture was mineralized by purging CO_2 continuously. Throughout the procedure, CO_2 was strictly controlled, including exclusion and injection. To achieve a high degree of mineralization, the flow rate, reaction temperature and concentration of cellulose dispersion were carefully optimized. Viscosity measurements, optical microscopy, and dynamic light scattering were used to examine the properties of the dispersions and cellulose-$Ca(OH)_2$ mixtures. A comprehensive assessment of the physicochemical characteristics of the hybrid material was conducted using thermogravimetric analysis, mechanical testing, spectroscopic methods, and electron microscopy to evaluate its composition, loading efficiency, and microstructural features.

By integrating the principles of biomineralization with engineered carbon capture and utilization, low-grade biomass and industrial waste can be transformed into high-value, climate-positive products at a dramatically accelerated rate.

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C3 - AGE-INDUCED CHANGES IN CELLULOSE NANOSTRUCTURE OF COTTON TEXTILES STUDIED BY COMBINED SCATTERING AND MODELING

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

AGE-induced changes in cellulose nanostructure of cotton textiles studied by combined scattering and modeling

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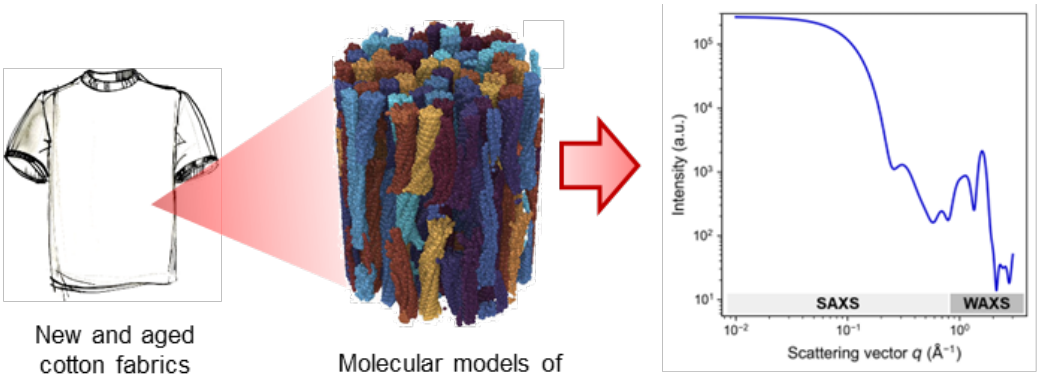
Age-induced changes in the structure and properties of polymer materials are highly relevant in various contexts, from paper and textile recycling to marine pollution and preservation of cultural heritage. In particular, the recycling of common cellulosic textiles such as cotton fabrics would greatly benefit from a better understanding of these changes and methods to study them efficiently. Based on our previous work [1], we aim to develop a high-throughput method for characterising the age-induced degradation of cotton fibers, based on near infra-red (NIR) spectroscopy and machine learning. To address the nanoscale mechanisms of the degradation and to form a link to different experimentally observable properties, we utilize the combination of X-ray scattering and molecular modeling [2].

We conduct systematic X-ray scattering experiments on cotton textiles with different degrees of degradation induced by chemical treatments and laundering. We aim to detect changes in the crystalline structure and crystallinity by wide-angle X-ray scattering (WAXS) and differences in the arrangement of cellulose microfibrils with small-angle X-ray scattering (SAXS). Possible degradation mechanisms will be modeled using a combination of stochastic and dynamic molecular simulations. The models will be linked to the experimental scattering results through scattering intensities computed from the models [3]. The results will serve as a basis for the NIR-based characterization method and elucidate the mechanisms of structure and property changes in cotton textiles during their use, supporting their efficient recycling.



New and aged cotton fabrics

Molecular models of nanostructural damage

Experimental and simulated X-ray scattering

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C4 - The effect of storage on the nano-structure and monosaccharide composition of pectin obtained from apple (Malus domestica cv. Golden Delicious)

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

The effect of storage on THE nano-structure and MONOSACCHARIDE COMPOSITION OF pectin obtained from APPLE (MALUS DOMESTICA CV. GOLDEN DELICIOUS)

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Pectin is a heteropolysaccharide abundant in the cell walls and middle lamella of plants. When extracted, it can adopt various conformational states at primary, secondary, and higher-order levels, depending on numerous intrinsic and external factors [1]. In climacteric species such as apple fruit (*Malus domestica*), the physicochemical properties of pectin are closely related to biochemical changes occurring during postharvest maturation. Given the high commercial potential of fresh apples, as well as matured, shelf-stored, processed, and revalorized apples, understanding the physicochemical properties of different pectin fractions is of primary importance. Thus, the purpose of this study was to evaluate how common postharvest storage applied to apple fruit affect the physicochemical properties of pectin.

Apple fruit (*Malus domestica cv.* Golden Delicious) was harvested during the 2024 season. Three distinct postharvest stages were defined: optimum harvest time (S1), after six months of cold storage (S2), and after 12 days of shelf life (S3). Several pectin fractions, namely water-soluble (WSP), chelator-soluble (CSP), and dilute alkali-soluble (DASP), were obtained through a sequential extraction process [2]. These pectin fractions were then subjected to structural analysis using atomic force microscopy surface topography images, in addition with image analysis techniques. Chain length, chain height and mean-squared end-to-end distance persistence length was evaluated using homemade scripts [3], while the molar percentages of homogalacturonan and rhamnogalacturonan-I were evaluated as reported previously [4]. Monosaccharide composition was determined using gas chromatography with flame ionization detector.

Acknowledgement

Current study was supported by the National Science Centre, Poland as a part of OPUS26 project (grant nr – 2023/51/B/NZ9/02121).

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C5 - MOLAR MASS MATTERS: ENHANCED SEC ANALYSIS FOR HEMICELLULOSE-RICH SAMPLES

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Molar Mass Matters: Enhanced SEC Analysis for Hemicellulose-Rich Samples

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Molar mass distribution (MMD) is a crucial parameter for characterizing cellulosic materials in both research and industrial applications. Among the available techniques, size exclusion chromatography coupled with multi-angle light scattering (SEC-MALLS) in a DMAc/LiCl solvent system stands out as the most powerful method for precise MMD determination.

In the context of growing sustainability concerns, paper-grade pulp has recently emerged as a promising alternative to conventional dissolving-grade pulp for man-made cellulosic fiber production due to its lower cost and environmental benefits. However, the high hemicellulose content in such pulps often causes significant challenges for dissolution, making an accurate characterization difficult. Nevertheless, analyzing the MMD of such samples is essential for evaluating polymer degradation, assessing spinnability, and characterizing the resulting fibers.

In this work, we present a novel method tailored for the MMD analysis of these challenging samples. Building on our previous findings on the favorable effect of DMSO activation in improving cellulose dissolution, we incorporated this approach into our protocol and further optimized it to prevent the loss of hemicellulose fractions. We believe this method offers a robust and reliable tool for analyzing complex pulp systems and will support the broader shift toward more sustainable fiber production.

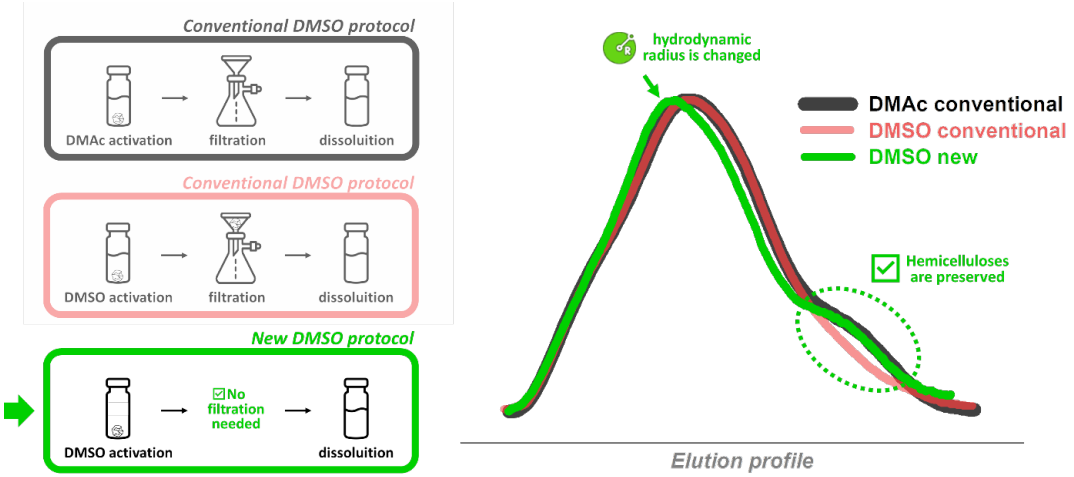

Figure 1. Comparison of conventional (DMAc or DMSO with a filtration step) and newly developed DMSO-based activation protocols for MMD analysis of hemicellulose-rich pulp samples using SEC-MALLS.

C6 - UNDERSTANDING THE STRUCTURE OF CELLULOSE NANOCRYSTALS USING 2D SOLID STATE NMR

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Understanding the structure of cellulose nanocrystals using 2D solid state NMR

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Cellulose nanocrystals (CNCs) are bio-sourced nanoscale building blocks. They are used in various fields owing to their excellent chemical, mechanical, and optical properties. CNCs organize as cholesteric liquid crystals, producing structural color solely upon treatment with sulfuric acid, which modifies their surface by introducing charged sulfate groups [1] [2]. Nonetheless, the structure of the CNCs and the susceptibility of glycosyl residues to sulfation in the cellulosic material remain poorly understood due to the constraints in peak resolution associated with 1D solid-state NMR (ssNMR) utilizing ^{13}C unlabeled samples.

This study investigates the cellulose structure and surfaces in CNCs that have undergone sulfation, partial desulfation, and no sulfation, utilizing ^{13}C 1D and 2D ssNMR to ascertain which glycosyl residues in the source material are likely to be sulfated. In addition, we have employed chemical composition analysis, microscopy, and wet chemistry to further characterize these CNCs. This work provides novel insights into the structure and surfaces of CNCs to further enable the better design of biomaterials with desirable material properties for various applications.

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C7 - The structural characterization of Exopolysaccharides produced by three marine microalgae species belonging to Tetraselmis genus

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

THE STRUCTURAL CHARACTERIZATION OF EXOPOLYSACCHARIDES PRODUCED BY THREE MARINE MICROALGAE SPECIES BELONGING TO *TETRASELMIS* GENUS.

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The genus *Tetraselmis*, a green marine microalga of the order Chlorodendrales, has garnered significant attention in various applications. These species are widely employed in nutraceuticals for their antioxidant properties [1] and serve as a valuable feedstock in aquaculture due to their high EPA content [2]. Furthermore, the substantial lipid content of *Tetraselmis* species make them a promising biofuel source [3]. Finally, several *Tetraselmis* species have been observed to produce extracellular polysaccharides (EPS) [4]. Studies have revealed that certain cultivation conditions, particularly heterotrophic growth, enhance EPS production in this genus [5]. These EPSs have substantially shown different biological activities, such as the EPS derived from *Tetraselmis suecica*, which has cytotoxic effects on tumor cells and exhibited antioxidant properties [6].

This investigation focuses on three distinct strains: *T. chuii*, *T. suecica*, and *T. suecica* 22D. These strains were cultivated under autotrophic, heterotrophic, and mixotrophic conditions to maximize EPS yields. Following extraction and purification, the structural characterization of the obtained EPS was conducted using chemical analyses and NMR spectroscopy.

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C8 - Surface Modification Of Carboxylated Cellulose Nanocrystals Via Post-Sulfation

Polysaccharide Colloids
Chemistry, Biology & Physics

Surface Modification Of Carboxylated Cellulose Nanocrystals Via Post-Sulfation

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Ammonium persulfate oxidation (APS) is a simple and environmentally friendly method for producing cellulose nanocrystals (CNCs) [1]. However, the carboxyl functional groups introduced by APS oxidation provide surface charges that are sensitive to pH, resulting in weak electrostatic repulsion at lower pH ranges, which affects their ability to self-assemble into chiral nematic liquid crystal phases. To effectively enhance the chiral nematic order, we introduced sulfate half-ester groups onto the CNC surface through post-sulfation, thereby increasing electrostatic repulsion. The modified CNCs retained both carboxyl and sulfate functional groups. Kraft paper was used as the starting material, utilizing APS oxidation first, followed by sulfuric acid treatment at 55% wt., following an established protocol [2]. A comprehensive characterization was conducted to compare the structural and surface properties. The variation in chemical composition of CNCs before and after post-sulfation was quantitatively evaluated using X-ray photoelectron spectroscopy (XPS).

Additionally, atomic force microscopy (AFM), dynamic light scattering (DLS), and X-ray diffraction (XRD) were employed to assess morphology, size distribution, and crystallinity. Fourier transform infrared spectroscopy (FTIR) and zeta potential measurements confirmed the chemical modifications and surface charge. We anticipate the presented methodology as a simple path toward sulfated CNCs without the need for alkali and delignification pretreatments of raw lignocellulosic materials.

Figure 1. XPS survey spectra of (a) the raw kraft paper and (b) CNCs after APS oxidization and post-sulfation (right).

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C9 - SYNTHESIS AND CHARACTERIZATION OF CYCLODEXTRIN-AHL HYBRIDS

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Synthesis AND CHARACTERIZATION of Cyclodextrin-AHL Hybrids

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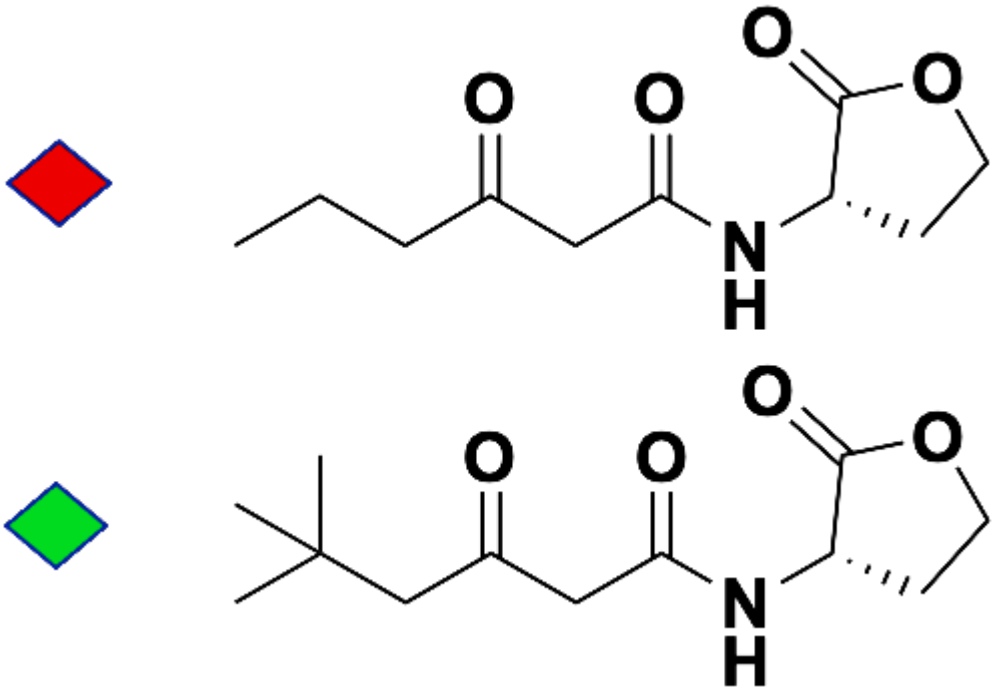
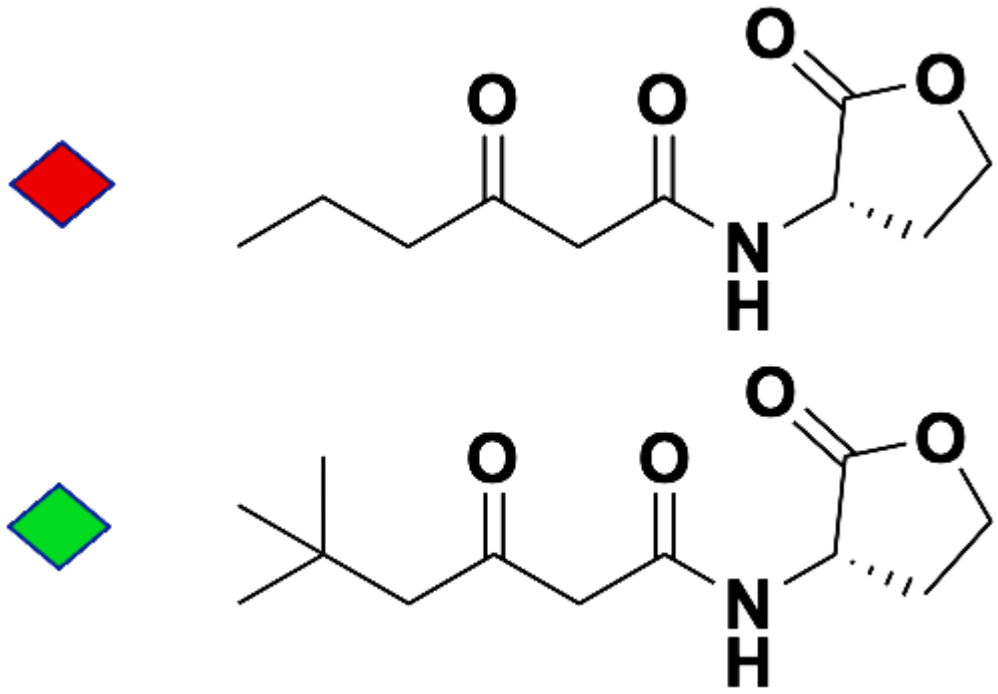
The phenomenon of Quorum Sensing (QS) has been **identified** in many Gram-negative bacteria, and the most studied low-molecular-weight signal molecules are acyl homoserine lactones (AHLs), whose structural variations depend on the bacteria. Several AHL analogues have been shown to modulate QS *in vitro* with a wide range of potential applications [1]. The cyclodextrin is a cyclic oligosaccharide derived from starch by a technological process. Attaching biomolecules onto a cyclodextrin scaffold is a known strategy to enhance their properties [2], but designing CD-AHLs conjugates has never been reported. In this work, we have grafted AHLs onto cyclodextrins by CuAAC "click" coupling between alkynyl-AHLs and 6-azido cyclodextrins derived from α-, β- and γ-CD, native or methylated. These molecules were fully characterized by NMR and HRMS, and the study of their solubility and conformation revealed significant conformational changes due to the presence of the AHL appendage and the CD structure. One of the hybrids (perAHL-β-CD, 9B) exhibited higher solubility than AHL and β-CD alone.





b)

a)

Fig. 1 a)General structure of the final molecules, b)Examples of agonist (red) and antagonist (green)

[1] Stacy, D. M.; Le Quement, S. T.; Hansen, C. L.; Clausen, J. W.; Tolker-Nielsen, T.; Brummond, J. W.; Givskov, M.; Nielsen, T. E.; Blackwell, H. E. *Org Biomol Chem* **2013**, *11 (6)*, 938–954.

[2] Alali, U.; Vallin, A.; Bil, A.; Khanchouche, T.; Mathiron, D.; Przybylski, C.; Beaulieu, R.; Kovensky, J.; Benazza, M.; Bonnet, V. *Org. Biomol. Chem*. **2019,** *17(30),* 7228–7237.

C10 - Structural characterization of chromophoric compounds within the analysis of total uronic acid contents using the m-hydroxybiphenyl assay

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

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Uronic acids, including galacturonic, glucuronic, mannuronic, and guluronic acids, play a crucial role in the structural integrity of polysaccharides such as pectin, xylan or alginate, which have important industrial and research applications. The quantification of the total uronic acid contents is essential for the characterization of polysaccharides, especially dietary fiber samples. The widely used method, introduced by Blumenkrantz and Asboe-Hansen in 1973, involves the degradation of uronic acids with concentrated sulfuric acid containing sodium tetraborate, followed by the addition of m-hydroxybiphenyl (mHB), resulting in the formation of a pink chromophore suitable for photometric analysis [1]. However, this method has significant limitations, including susceptibility to interference from neutral sugars, and a comprehensive structural elucidation of the chromophore is required to improve analytical accuracy by optimizing the analytical workflow.

In this study, the mechanism of chromophore formation was investigated revealing that the specific degradation product of uronic acids, 5-formyl-2-furancarboxylic acid (5FFA), reacts with mHB under anhydrous acidic conditions to form a colored complex, which undergoes reversible decolorization upon hydration. To further characterize the chromophore structures, precursor compounds were isolated from the reaction of 5FFA with mHB. After dilution with sodium hydroxide, five different aromatic reaction products were separated by ethyl acetate extraction, analyzed by UHPLC-DAD/MS and subsequently enriched by semi-preparative fractionation. The isolated compounds developed the characteristic pink color upon acidification with sulphuric acid and exhibited molecular masses of 462 g/mol, 584 g/mol, and 754 g/mol.

Structural characterization by 1D- and 2D NMR spectroscopy confirmed the formation of 5-(bis(3-hydroxybiphenyl))furan-2-carboxylic acid isomers via the reaction of 5FFA with two mHB molecules. Further polymerization products were hypothesized based on the substitution of additional 5FFA molecules or 5FFA-mHB dimers. To further substantiate the proposed chromophore structures, quantum chemical calculations were performed and compared with experimentally determined UV-vis absorption spectra.

[1] Blumenkrantz, N.; Asboe-Hansen, G., New method for quantitative determination of uronic acids. Analytical Biochemistry 1973, vol. 54 (2), 484-489.

C11 - SEMI-SYNTHESIS OF PHOSPHORYLATED GLYCOSAMINOGLYCANS

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

SEMI-SYNTHESIS OF PHOSPHORYLATED GLYCOSAMINOGLYCANS

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Glycosaminoglycans (GAGs) are highly complex, anionic, linear polysaccharides extracted from extracellular matrix of animals cells. They are typically composed of disaccharide repeating units, that are very often extensively decorated with sulfate groups. Some of them are exploited in already approved therapeutic treatments, and a significant number of novel drugs are currently under development [1]. Nonetheless, naturally occurring GAGs exhibit variable chemical compositions and biological activities, which could cause unpredictable results during applications (*e.g.* heparin crisis in 2007). In this frame, in recent years several research efforts have been spent to synthetize artificial GAG mimics [2]. In this context an interesting topic concerns phosphorylated GAGs. Indeed, phosphate *vs.* sulfate differences in size, polarity, acid-base and chelation properties could lend unreported activities to phosphorylated GAGs, as indicated by an *in silico* study comparing the structural flexibility and intra- and intermolecular interaction patterns of native GAGs with their phosphorylated counterparts. [3] Actually, this theoretical investigation suggested that phosphorylated GAGs could bind proteins generally with a stronger affinity than their sulfated counterparts and the differences in the binding modes might be highly protein target-dependent. This would propose phosphorylated GAGs as promising, new species to specifically control biochemical processes where the mediating role of sulfated GAGs is crucial. Nonetheless, the preparation of phosphorylated GAGs is still rather underdeveloped, [3-5]. In this communication we present the results of a screening of both multi-step strategies and direct phosphorylation methods – relying upon either standard or innovative phosphorylation reactions – applied on unsulfated GAG-like polysaccharides from microbial sources. [6]

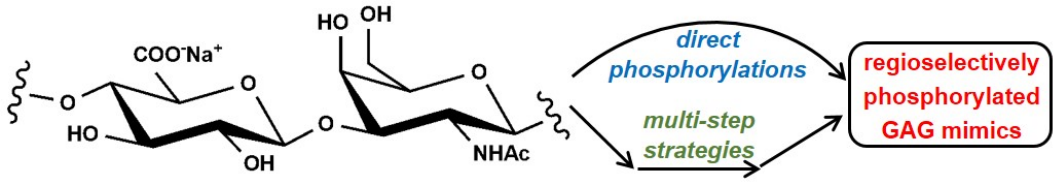

Figure 7 **Figure 1 - General approach for regioselective phosphorylation of GAG-like polysaccharides**

References:

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C12 - Quantitation of NITRITES in MICROCRYSTALLINE CELLULOSE and HYPROMELLOSE by Ion Chromatography / Mass Spectroscopy

Compositional Analysis
Chemistry, Biology & Physics

QuantitaTion OF Nitrites in Microcrystalline Cellulose And Hypromellose by Ion chromatographyC / Mass specrtroscopy

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N-nitrosamines are considered probable or possible human carcinogens and have been detected in drug products. FDA, EMA and other pharma regulatory bodies across the world have requested pharmaceutical companies to evaluate, investigate, and control the formation of nitrosamines to ensure the safety and quality of drug products. One mechanism for nitrosamine formation involves the reaction of secondary or tertiary amines with a nitrosating agent. Many active pharmaceutical ingredients (API) contain amines. Nitrite can form a nitrosating agent under acidic conditions and the presence of nitrites has been detected in excipients. Many pharmaceutical companies are looking for excipients that contain no nitrites or very low levels of nitrites as part of their nitrosamine risk mitigation plans. In response to this need, IFF is offering Low Nitrite Avicel® PH Microcrystalline Cellulose (MCC) and Low Nitrite METHOCEL™ Hypromellose (HPMC) products. These low nitrite excipients can be tools for pharmaceutical companies to mitigate the risk of N-nitrosamine formation in drug products. To provide a product with low nitrite content, there is a need for accurate, specific, and sensitive methods for measuring nitrites in the low parts-per-billion (ppb) range. The most-used nitrite methods for excipients are based on either ion chromatography (IC) coupled with conductivity detection (CD) or on Griess assay. When using IC/CD to detect low levels of analyte, co-eluting species from the matrix can complicate quantification of nitrite and cause inaccurate nitrite results. At IFF, we have developed and validated IC mass spectrometry (MS) methods, capable of selectively detecting nitrite to eliminate co-elution and accurately quantify low levels of nitrite in Microcrystalline Cellulose (MCC) (limit of quantitation of 16 ppb) [1] and Hypromellose (HPMC) (limit of quantitation of 30 ppb) [2].

[1] Zhu, Koudi; Kerry, Michael; Serr, Barbara; Mintert, Markus; *Journal of Pharmaceutical and Biomedical Analysis* 235 (2023) 115648

[2] Zhu, Koudi; Kerry, Michael; Serr, Barbara; Mintert, Markus; Pursch, Matthias; Eeltink, Sebastiaan; Desmet, Gert; *Journal of Pharmaceutical and Biomedical Analysis* 248 (2024) 116330

C13 - OLFACTORY FINGERPRINT OF 19TH CENTURY DOCUMENTS – A QUALITATIVE GC×GC STUDY

Compositional Analysis
Chemistry, Biology & Physics

Olfactory fingerprint of 19th century documents – a qualitative GC×GC study

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The typical scent of old books and aged paper in general captures the interest of both the scientific and lay communities. This well-known nostalgic aroma is composed of a wide variety of volatile organic compounds (VOCs) emitted during the degradation processes of lignocellulosic material. The most commonly used tool for VOC qualitative analysis is a combination of solid-phase microextraction with gas chromatography and mass spectrometry (SPME-GC-MS). However, the complexity of the mixture combined with choosing one type of stationary phase for its separation leads to the inevitable coelution of some compounds. In this study, we used comprehensive two-dimensional gas chromatography (GC×GC) coupled with MS detection, in which two stationary phases with different selectivity were used to separate the olfactory fingerprint of two documents from the 19th century (1836 and 1875). The presented results express the power of GC×GC in the world of cultural heritage, where often very complex samples need to be analysed and understood.

C14 - NOVEL STATIONARY PHASE FOR HIGH-RESOLUTION SEPARATION OF CARBOHYDRATES IN BIOMASS HYDROLYZATES

Compositional Analysis
Chemistry, Biology & Physics

Novel Stationary Phase for High-Resolution Separation of Carbohydrates in biomass hydrolyzates

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High Performance Anion-Exchange Chromatography (HPAEC) is one of the most powerful analytical technique for carbohydrate analysis due to its ability to separate all classes of alditols (polyols), aminosugars, mono-, oligo- and polysaccharides including glycans, according to structural features such as size, composition, anomericity and linkage isomerism.

A novel agglomerated pellicular anion-exchange stationary phase SweetSep™ AEX20 has been developed for the separation of complex carbohydrate samples [1]. AEX20 is based on a monodisperse 5 µm resin of highly crosslinked poly(divinylbenzene-co-ethylvinylbenzene) copolymer coated with nanoparticles functionalized with dual ion exchange sites (quaternary amine and tertiary amine). The high uniformity and monodispersity of the AEX20 resin allow for fast, high-resolution separations of carbohydrates that can rival the performance of some stationary phases based on 4 µm particle technology, but operate with significantly lower back pressures. The size and exchange capacity of the AEX20 latex nanoparticles was optimized for the reproducible separation of mono- and disaccharides in a wide variety of carbohydrate samples including, food, plants, glycoproteins and biomass samples. The AEX20 is available as a microbore column with 2.1 mm ID, which minimizes solvent consumption and waste, and thus environmental impact. The column is particularly suitable for the compositional analysis of biomass hydrolyzates to quantify the released neutral sugars and uronic acids. As an example, the neutral sugars and uronic acids typically present in biomass hydrolysates are shown in figure 1. Examples of the sensitive HPAEC-PAD analysis of several different types of biomass hydrolyzates will be presented, such as seaweed, wood, chitin and cellulose pulp.

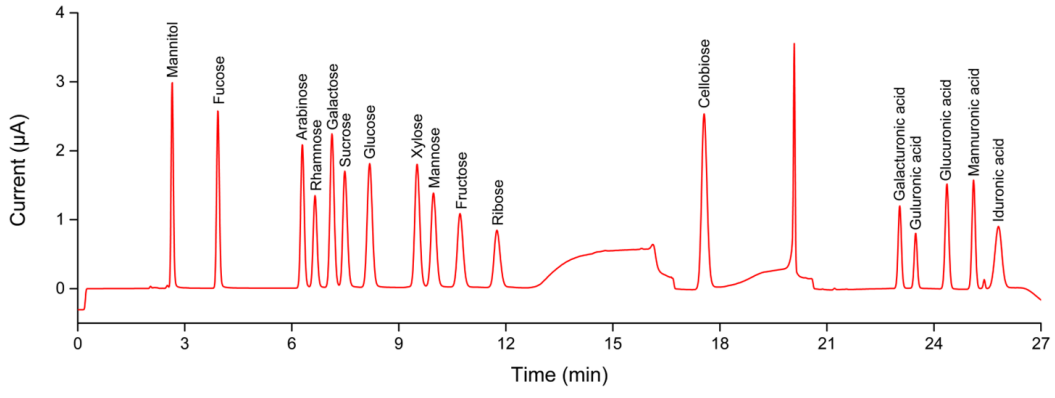

Figure 1. Chromatogram obtained from a 3 µL injection of a 100 µM standard mix consisting of 12 neutral sugars and 5 uronic acids in DI water using a SweetSep™ AEX20 200 × 2.1 mm ID column. The black ↑ arrows indicate the start of a baseline elevation due to the changes in mobile phase composition (step gradient).

[1] C.Marvelous, T. Mulder, J-P. Chervet, N.J. Reinhoud, H-J. Brouwer, *Journal of Chromatography A*, **2024**, 1716, 464661, https://doi.org/10.1016/j.chroma.2024.464661

C15 - NANOSCALE INSIGHTS INTO WOOD CELL WALLS

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Nanoscale Insights into Wood Cell walls

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The wood cell wall is a complex structure made of several different compounds such as cellulose, hemicellulose, lignin, and pectin [1]. However, its complex structure and composition renders it as a very difficult target to study, and also the nanoscale interactions between these components remain largely unexplored. Isolating and separating wood cell wall components is time-consuming, requires large amounts of material and involves various treatment processes often altering their structure. FT-IR spectroscopy provides a solution by analyzing components directly without extraction. In addition to analyzing the composition of different layers of wood cell walls (Primary (P), Seconadry (S1,S2,S3)), our study aims to understand the assembly of cell wall polymers at the nanoscale level, contributing to the formation of a functional cell wall structure.To achieve this, we are using nano FTIR spectroscopy, which is a combination of IR spectroscopy and atomic force microscopy (AFM), which offers a spatial resolution of 20 nm [2]. This approach reveals the structural heterogeneity of wood cell walls at the nanolevel along with IR imaging to understand cell wall interactions. By using this technique, we can explore the nanoscale physicochemical properties that distinguish the secondary cell wall (SCW) and compound middle lamella (CML) of wood. On the basis of the characteristic peaks of isolated cellulose, hemicelluloses and lignin, the nano-FTIR absorbances were plotted against the location in the cell wall region. In our study, we found that the cellulose absorption peaks appear in the S2 at 1068 cm^{-1} and 1164 cm^{-1}. Understanding the lignin distribution in the SCW and CML of plants offers crucial insights at a fundamental level. The lignin peak was clearly observed around 1510 cm^{-1} in the CML showing its larger abundance in the CML compared with the SCW. Observing spatial changes in cell wall composition and properties through imaging is crucial for deepening our understanding of wood cell wall structure.

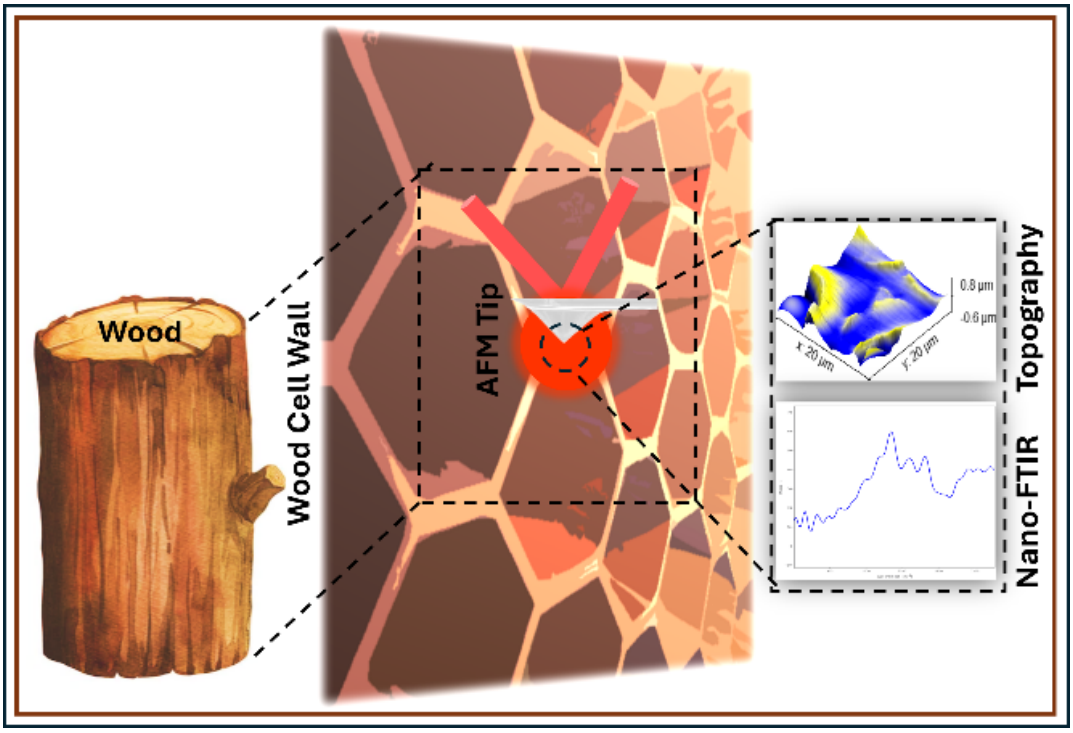

Figure 1. Illustration of Nano FTIR spectroscopy applied to study the wood cell wall.

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[2] Huth, Florian, et al, Nano letters 2012, 12.8 3973-3978.

C16 - Multifunctional Chitooligo and -polymers throught Selective Chemo-Enzymatic Functionalization

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Multifunctional chitooligo and -polymers

through selective chemo-enzymatic functionalization

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Chitin Deacetylases (CDAs) are not only a group of naturally occurring enzymes that can be found in various organisms, but also a powerful tool for the synthesis of chitooligomers and -polymers with defined Patterns of Acetylation. Here, the pattern specificity during CDA catalyzed de- and re-*N*-acetylation is governed by different effects, that are inherent to most CDAs and -up to now- make CDAs the only available synthetic tool (chemically and biocatalytically) to obtain chitooligomers and -polymers of the so-called 3rd generation [1].

However, CDAs are not limited to de- and re-*N*-acetylation activity but some also accept a bandwidth of carboxylates, other than acetate, that enables a powerful regioselective and orthogonal de- and re-*N*-acylation activity.

Since „click"-reactive carboxylates can be converted as well, utilization of CDAs *N*-acylation activities allow –in combination with chemical functionalization- the synthesis of multifunctional chitooligo- and polymers [2]. Thereby, the expected non-random Patterns of Substitution not only results in functionalized chitosans with possibly novel physico-chemical and biological properties, but also site-specific functionalization of the non-reducing end allows the synthesis of bifunctional telechelic chitooligomers and -polymers.

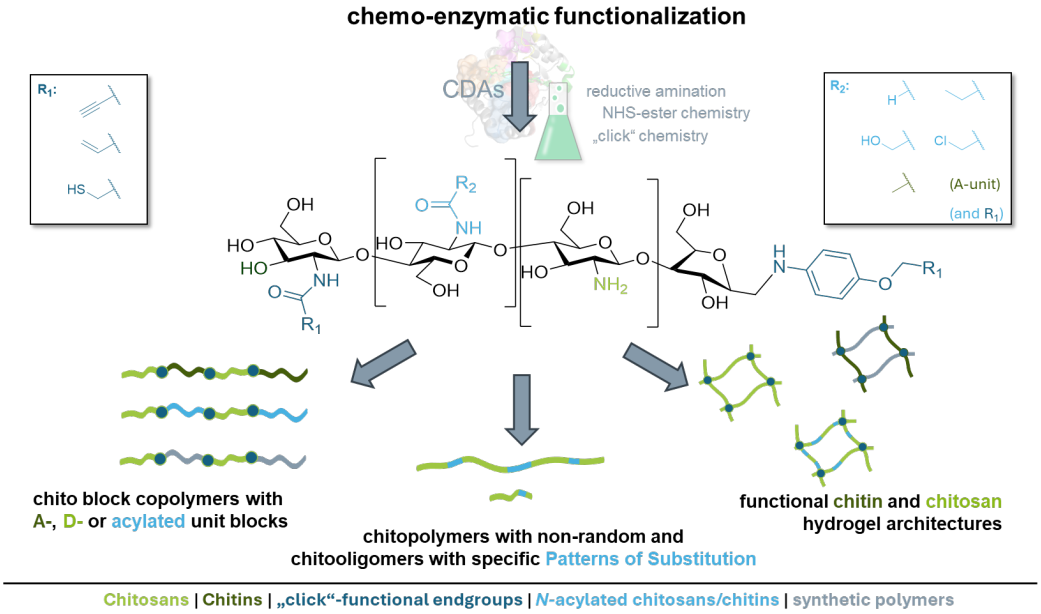

Figure 1. General scheme of selective chemo-enzymatic chitooligomer and polymer functionalization based on CDA's *N*-acylation activity.

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C17 - DESIGN AND EVALUATION OF RHODAMINE-CONJUGATED CHITOSAN POLYELECTROLYTE COMPLEX NANOPARTICLES FOR ANTIMICROBIAL THERAPY

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Design and Evaluation of Rhodamine-Conjugated Chitosan Polyelectrolyte Complex Nanoparticles for Antimicrobial Therapy

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Chitosan polyelectrolyte complex (PEC) nanoparticles have garnered significant attention in biomedical and pharmaceutical applications, particularly in antimicrobial therapy [1-3]. These nanoparticles are formed through the electrostatic interaction between chitosan, a positively charged biopolymer [4], and negatively charged polyelectrolytes like chondroitin sulfate. The objective of this study was to optimize formulation parameters and explore the remarkable potential of PECs in advancing drug delivery applications. In this work, positively charged biopolymers such as chitosan betaine (TAC), chitosan oligomer rhodamine, chitosan rhodamine, and TAC-ciprofloxacin [5-6] were synthesized using HATU coupling and Click reactions (**Scheme 1**). Anionic biopolymers, including chondroitin sulfate (CS) and chondroitin sulfate fluorescein (CSF), were utilized to create the PEC nanoparticles. The conjugated chitosan was characterized using NMR, while the formation of PEC nanoparticles was confirmed through various experimental techniques, including Dynamic Light Scattering (DLS), Fluorescence Resonance Energy Transfer (FRET) measurements, and Transmission Electron Microscopy (TEM). Minimum Inhibitory Concentration (MIC) and well diffusion antimicrobial assays demonstrated that TACs were effective against both Gram-positive and Gram-negative bacteria, with their activity positively correlated with the degree of substitution (DS). TAC showed slightly reduced activity when formulated into PEC nanoparticles; however, TAC-Cip exhibited 30 to 60 times more effectiveness against the Gram-negative bacterium E. coli. Notably, hydrolyzed TAC-Cip, which released the drug, was found to be 256 to 64 times more active against bacteria compared to TAC alone. Cell uptake studies revealed that using PECs significantly increased the cellular uptake of the polymers compared to the individual polymers used alone. Cytotoxicity tests confirmed that only TAC exhibited cytotoxic properties, while the PECs reduced this toxicity. These results suggest that PEC nanoparticles based on TAC, TAC-Rhodamine, and TAC-Cip could prove to be highly promising in the treatment of intracellular bacterial infections.

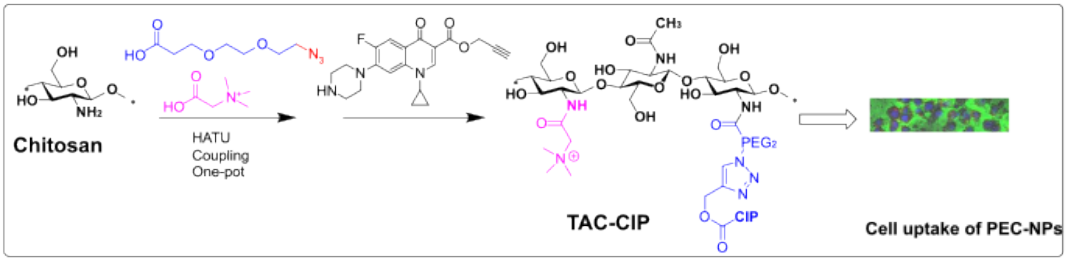

Figure 8 **Scheme 1. Synthesis of TAC-ciprofloxacin.**

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C18 - END-GROUP MODIFICATION OF CELLULOSE III NANOCRYSTALS WITH POLYETHYLENE GLYCOLS

Polysaccharide Colloids
Chemistry, Biology & Physics

END-GROUP MODIFICATION OF CELLULOSE III NANOCRYSTALS WITH POLYETHYLENE GLYCOLS

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In cellulose research, although the transformation of native cellulose crystals within macroscopic fibres to other allomorphs has been known for a few decades, investigations of cellulose nanocrystal (CNC) transformations and their modification is at its infancy. Most of the research has focused on the production and assessed features of cellulose nanocrystals I and II. Beyond the parallel and antiparallel chain arrangements that uniquely identify CNC I and CNC II, a third class of nanocrystals, allomorph III, is gaining more attention and deserves further exploration. The latter is generated starting from any of the two precursors via treatment with an amine, such as ethylene diamine, providing a cellulose nanocrystal that retains the chain arrangement of the allomorph from which it is generated, while differing in chain packing and unit cell size. Therefore, the chemical behaviour and properties of CNC III are expected to show a certain degree of divergence and novelty from the others. CNCs, other than earning popularity due to their low cost, renewability and availability, have attracted scientists to investigate potential chemical modifications, thus a range of applications, that could be achieved by exploiting the reactivity of the surface hydroxyl groups. The reducing end groups (REGs) that are present either asymmetrically or symmetrically according to the allomorph subject of study, can be functionalized via multiple routes such as ligation, Knoevenagel condensation, Pinnick oxidation and reductive amination. CNCs with end-tethered polymers have already been synthesized by multiple groups, however end-group modification of CNC allomorph III, to the best of our knowledge, has not been reported. The challenges of reacting this metastable crystal structure include its particular vulnerability to hydrothermal conditions. This work presents the modification of allomorph type III REGs with polyethylene glycol (PEG) derivatives. CNC-III is produced from native cellulose I obtained from two renewable resources and, following amine treatment, the reducing ends of CNC allomorph III are grafted with linear PEGs via reductive amination. The final product with parallel arrangement is characterized pre- and post modification by means of techniques such as FTIR spectroscopy, X-ray diffraction, elemental analysis and atomic force microscopy. We further present the effect of reactions conditions on the stability of CNC III allomorphs and propose paths forward to prevent reversion.

C19 - Laccase crosslinked arabinoxylan nanoparticles (AXTnp) act as a natural emulsifier for canola oil-based Pickering emulsion

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

Laccase crosslinked arabinoxylan nanoparticles (AXTnp) act as a natural emulsifier for canola oil-based Pickering emulsion

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The development of hemicellulose nanoparticles (HNPs) has become a key strategy to address the complex and heterogeneous structure of hemicellulose. This study aimed to fabricate laccase-crosslinked arabinoxylan nanoparticles (AXTnp) by an eco-friendly "anti-solvent precipitation" method using ethanol. AX was extracted from corn fibre by subcritical water, which preserves the ferulic acid moieties covalently bound to the polysaccharide core [1]. The preparation of AX nanoparticles was explored with and without the presence of laccase. Laccase crosslinked AX showed a 2-fold increase in the average particle size and increased homogeneity as compared to non-laccase treated AX observed using Dynamic Light scattering (DLS). The crosslinked and crude AX particles were further used as stabilizers for Pickering emulsion using 10% v/v canola oil. Laccase crosslinked AX-based emulsions showed a distribution of small (1-10μm) and large (10-100 μm) oil droplets whereas uncrosslinked AX based emulsions majorly comprised of small droplets (1-10 μm). The emulsions were characterized using confocal laser scanning microscopy (CLSM) and optical microscopy to study the trends of the droplet size distribution and their storage stability. Laccase crosslinked AX based emulsion showed better stability (higher zeta potential) on storage as compared to uncrosslinked AX based emulsion. This opens the way to upcycle agricultural side streams into novel food ingredients, with derived sustainability and health benefits.

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C20 - EXPLORING NOVEL SOURCES OF L-RHAMNOSE: EXTRACTION AND STRUCTURAL CHARACTERIZATION OF MICROALGAL POLYSACCHARIDES

Compositional Analysis
Chemistry, Biology & Physics

Exploring novel sources of l-Rhamnose: Extraction and structural characterization of microalgal polysaccharides

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l-rhamnose, a rare deoxy sugar, has significant applications in the food, pharmaceutical, and cosmetic industries as a key precursor in complex chemical and biochemical processes. Today, its production is mainly based on the hydrolysis of plant biomass, yielding insufficient quantities to meet the increasing market demand. Identifying alternative and sustainable sources of l-rhamnose is therefore crucial. The French Agence Nationale de la Recherche (ANR) RAh project [ANR-23-CE43-0011] aims to develop innovative strategies for the extraction and purification of l-rhamnose from underexplored terrestrial plants, bacteria, macro- and microalgae. In this study, exopolysaccharides (EPS) from seven microalgae and one cyanobacterium were produced under photoautotrophic batch conditions. Their mass yields, biochemical composition, and monosaccharide distributions were determined using a combination of colorimetric assays, Fourier Transform Infrared Spectroscopy (FTIR) fingerprints, and total acidic hydrolysis followed by trimethylsilylation (TMS) derivatization then Gas Chromatography/Mass Spectrometry with Electron Ionization (GC/MS-EI) analysis, enabling the identification of rhamnose-rich polysaccharides. Further structural elucidation was conducted via methylation analysis using an adapted Hakomori method [1], providing insights into glycosidic linkages and polysaccharide branching patterns. These results will guide the selection of specific CAZy hydrolases and lyases capable of depolymerizing these EPS, thereby facilitating the controlled release of l-rhamnose and oligorhamnan chains. This study represents a significant step toward sustainable biotechnological production of l-rhamnose, offering new opportunities for industrial applications.

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C21 - Effect of Reaction Condition on the Structural Characteristics of Cellulose Synthesized by Cellodextrin Phosphorylase

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Effect of Reaction Condition on the Structural Characteristics of Cellulose Synthesized by Cellodextrin Phosphorylase

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1. Introduction

Biomaterials are valued for their abundance, renewability, and excellent mechanical properties, which originate from the sophisticated molecular assembly of polymer chains in living organisms. Native cellulose exemplifies this harmony of properties and is crystallized into cellulose I, the polymorph with the highest stretching crystallographic Young's modulus, measured at 138 GPa[1)]. Understanding and controlling cellulose self-assembly mechanisms is essential for advancing fundamental biological insights and developing high-performance biomaterials. In this study, we investigated enzymatic cellulose synthesis by using cellodextrin phosphorylase (CDP) synthesis system as a model[2)], focusing specifically on the influence of temperature and octyl-glucoside (OG) acceptor concentration. By analyzing the structural variations of cellulose synthesized under different conditions, we aim to elucidate key factors—such as hydrophobic interactions or concentration-dependent interfacial effects—that govern molecular assembly during cellulose formation at ambient conditions.

2. Methods

CDP protein was produced by heterologously expressing the gene from *Acetivibrio thermocellus* (formerly *Clostridium thermocellum*) in *Escherichia coli* BL21(DE3). The produced protein was purified with immobilized metal affinity chromatography and desalting. Purified CDP was used to catalyze reactions with glucose or octyl-β-D-glucoside (OG) in the 500 mM HEPES-NaOH (pH 7.5) buffer at either 60 °C or 40 °C. The reaction products were analyzed using ATR-FTIR, an optical microscope with birefringent detector, SEM, TEM, MALDI-TOF-MS, electron diffraction, and SAXS.

3. Results and Discussion

To investigate how reaction conditions affect cellulose self-assembly, we synthesized cellulose using CDP at different temperatures (40 °C and 60 °C) and octyl-glucoside (OG) concentrations (10 mM and 50 mM). Microscopic and FTIR analyses revealed that in all conditions, cellulose I was

consistently synthesized, indicating that cellulose I formation is not dependent on micelle formation by OG, as previously reported[3]. Instead, a lamellar structure was identified as the elementary unit of cellulose I across all samples, which further aggregated into spherical assemblies.

Interestingly, the reaction at 60 °C with 10 mM OG produced spherical aggregates with a more uniform size distribution, suggesting that lower OG concentrations may facilitate more homogeneous aggregation. Model fitting analysis of SAXS data further supported the TEM, showing that the lamellar thickness remained constant throughout the reaction, implying a continuous formation of structurally uniform lamellae.

At 40 °C, the reaction with 10 mM OG yielded similar results to those at 60 °C. In contrast, the reaction with 50 mM OG and prolonged incubation (>12 h) produced a distinct pipe-like morphology, as observed by electron microscopy. Notably, this morphology was synchronized with cellulose II signals in FTIR, and electron diffraction analysis confirmed that the pipe-like structures were composed of cellulose II. Given that the lamellar structure of cellulose I was always dominant during the synthesis, it is likely that the pipe-like structures emerged through aggregation of these lamellae. This suggests a possible conversion from cellulose I to cellulose II during the later stages of structural organization.

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C22 - EFFECT OF ENZYMATIC DELIGNIFICATION ON SUBCRITICAL WATER EXTRACTION OF HEMICELLULOSES

Extraction & Purification
Chemistry, Biology & Physics

eFFECT OF ENZYMATIC DELIGNIFICATION ON SUBCRITICAL WATER EXTRACTION OF HEMICELLULOSES

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Hemicelluloses are essential components of wood materials, playing a key role in connecting cellulose fibers and lignin within plant cell walls. They influence the structure and mechanical properties of wood, creating areas of both rigidity and flexibility that are crucial for its overall strength and function. Hemicelluloses are often underused in industry, especially in the pulp sector, where they are typically broken down during traditional processing methods. This degradation limits their potential in material applications and highlights the need for gentler, more sustainable methods that can preserve their natural structure [1].

Subcritical water extraction (SWE) is a promising method for extracting hemicelluloses, offering the added benefit of unlocking their potential for innovative applications, such as the creation of hydrogels for biomedical purposes. In previous works, we have applied subcritical water extraction to different woody biomass for the selective extraction of hemicelluloses [2-3]. The extraction process is conducted without previous delignification at 170°C under slightly acidic conditions at pH 5. In this work we will examine the effect of an enzymatic pretreatment prior to subcritical water extraction on the yield, composition, and properties of the hemicelluloses. This study aims to provide insight into how different pretreatments affect the quality and potential applications of the extracted hemicelluloses using subcritical water.

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C23 - CHARACTERIZATION OF VIBRIO CRASSOSTREAE SURFACE GLYCANS AND ITS POTENTIAL ROLE IN BALD SEA URCHIN

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

Characterization OF *VIBRIO CRASSOSTREAE* SURFACE GLYCANS AND ITS POTENTIAL ROLE IN BALD SEA URCHIN

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Vibrio species are widely distributed microorganisms in aquatic environments, where they can exist either as free-living bacteria or in association with various marine organisms. Their high biodiversity and pathogenic potential make disease management in aquaculture particularly challenging [1,2].

Among these bacterial species, *Vibrio crassostreae* is a Gram-negative bacterium known for its pathogenicity towards various marine species, contributing to significant losses in the aquaculture industry.

Following a mortality event of sea urchins (*Paracentrotus lividus*) on Procida Island, microbiological analyses were performed on the tissues and spines of affected specimens.

This study aims to analyze the surface glycans of *Vibrio crassostreae* to provide a reference framework for future research investigating its potential pathogenicity in sea urchins. Specifically, we seek to determine whether this bacterium may be involved in "bald sea urchin disease," a condition characterized by spine loss.

To isolate *Vibrio* species, soft tissues (esophagus and intestines) and spines from *P. lividus* were inoculated into 10 ml of Marine Broth (MB) and incubated at 30°C for 48 hours. Serial dilutions were subsequently performed, and 100 µl of the 10^{-2} and 10^{-3} dilutions were plated onto Thiosulfate-Citrate-Bile Salts-Sucrose (TCBS) Agar, a selective medium. Plates were then incubated at 30°C for 24-48 hours to allow *Vibrio* species to grow.

It has been observed that *Vibrio crassostreae* produces both a rough-type lipopolysaccharide (LOS) and a capsular polysaccharide (CPS). In this study, we analyzed the sugar composition of both glycans and conducted a detailed structural characterization of the capsular polysaccharide.

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C24 - COVALENT ANCHORING OF A CELLULOSE PER(PHENYL CARBAMATE) CHIRAL SELECTOR ONTO SILICA GEL BY ALKYNE-AZIDE CLICK CHEMISTRY AND ITS UTILIZATION IN HPLC

Bio-)Synthetic & Modified Polysaccharides
Chemistry, Biology & Physics

Covalent anchoring of a cellulose per(phenyl carbamate) chiral selector onto silica gel by alkyne-azide *click* chemistry and its utilization in HPLC

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High-performance liquid chromatography employing a chiral stationary phase is a powerful tool for enantioseparation. Cellulose-based chiral selectors exploit the polysaccharide's inherent homochirality and are among the most successful chiral separation materials. Compared to initial coating-type chiral stationary phases, in which the selector is deposited onto silica as the chromatographic support, covalently immobilized selectors exhibit a significantly broader scope of mobile phases, but appropriate synthetic strategies are still scarce.

In this work, we present a cellulose all-phenyl carbamate-type selector covalently immobilized to silica as the chromatographic support by means of a Cu(I)-catalyzed *Huisgen* alkyne-azide *click* reaction. Cellulose was first functionalized with 3,5-dichlorophenyl carbamate groups (DS = 2.35) and 4-propargyloxy-3,5-dichlorophenyl carbamate groups (DS = 0.45, overall DS = 2.80), and subsequently *clicked* to 3-azidopropyl-prefunctionalized silica gel as the chromatographic support, affording a 9 wt% covalently functionalized chiral stationary phase. The chiral selector was comprehensively characterized by ATR-FTIR and NMR spectroscopy and elemental analysis, including estimation of the degree of substitution. Additionally, coating-type chiral stationary phases

with 9 and 20 wt% loadings were prepared. All chiral phases were tested concerning their separation performance with a representative set of racemic analytes under conventional normal-phase conditions. Solvent compatibility and thus the chemical robustness of the immobilized stationary phase was studied using higher shares of stronger eluents, *i.e.*, ethyl acetate, tetrahydrofuran, and chloroform which would dissolve the selector in a coating-type setup. The covalently linked selectors showed enhanced separation performance and stability compared to the coating-type analogs.[1]

[1] Lehrhofer A. F.[1]; Petroni S.[1]; Bacher M.; Kohout M.; Schachamayr D.; Malyshenko A.; Rosenau T.; Cipolla L.; Hettegger, H. Covalent Anchoring of a Cellulose Per(Phenyl Carbamate) Chiral Selector onto Silica Gel through Alkyne-Azide Click Chemistry and its Utilization in HPLC. *Cellulose* **2025** (in press)

C25 - Colloidal stability of cellulose nanocrystal suspensions in the presence of ionic liquids

Polysaccharide Colloids
Chemistry, Biology & Physics

Colloidal stability of cellulose nanocrystal suspensions in the presence of ionic liquids

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Cellulose nanocrystals (CNCs), a class of nanomaterials derived from cellulose, are of a significant interest in research owing to their sustainability, colloidal dispersibility and highly anisometric morphology. In a general approach, CNCs are obtained as negatively charged particles forming stable colloidal suspensions in water[1], which can be thereafter chemically modified to obtain positively charged CNCs, a promising material for flocculation of microalgae[2]. However, preparation of positively charged CNCs generally requires the use of toxic chemicals such as pyridine[2]. Therefore, we are aiming at a more environmentally friendly procedure to obtain dispersible positively charged CNCs. One of the possible strategies is the surface overcharge, shown previously on CNCs in the presence of trivalent ions[3] and on sulfated polystyrene latex particles in the presence of hydrophobic ionic liquids (IL's)[4], which have gained attention as promising agents for extraction of nanoplastics[5].

Here, we studied colloidal behavior of sulfated CNCs in the presence of imidazolium-based IL's with different alkyl chain length with dynamic light scattering and electrophoretic light scattering. The IL's with short chain lengths did not cause surface overcharge, whereas in the presence of octylmethylimidazolium (*moim*) cation, we observed a surface overcharge similar to sulfated latex particles[4]. The similarity of colloidal stability of CNCs and the values of critical coagulation concentration (CCC) over a broad range of alkyl chain lengths of the IL's suggests that the alkylimidazolium counterions tend to adsorb onto the hydrophobic surfaces of the CNCs, in a similar manner to quaternary ammonium ions[6]. However, re-stabilization of CNCs did not take place, which is attributed to the higher hydrophilicity of CNCs compared to sulfated latex particles.

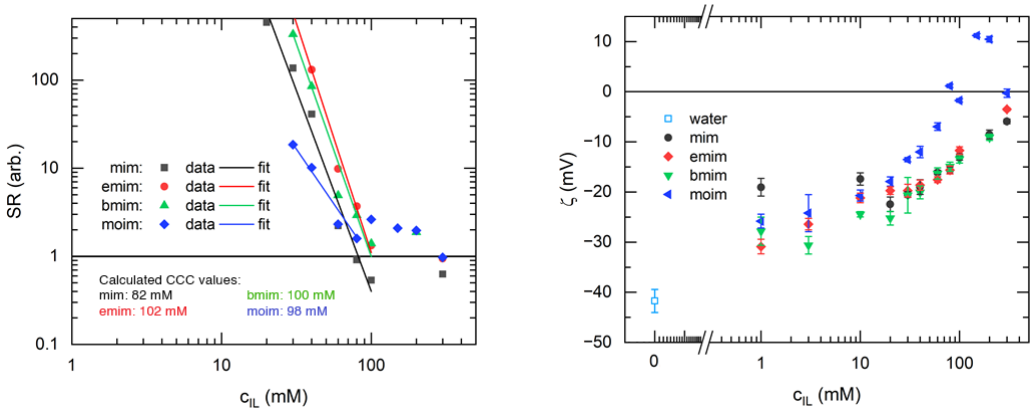

Figure 1. Stability ratio (left) and zeta potential (right) of sulfated cellulose nanocrystals suspensions as a function of concentration of an ionic liquid

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C26 - CHEMICAL FUNCTIONALIZATION OF POLYSACCHARIDES WITH SMALL MOLECULES: A 1H-NMR SPECTRUM IS NOT ALWAYS ENOUGH FOR CONFIRMING THE DERIVATIZATION

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

CHEMICAL FUNCTIONALIZATION OF POLYSACCHARIDES WITH SMALL MOLECULES: A ^{1}H-NMR SPECTRUM IS NOT ALWAYS ENOUGH FOR CONFIRMING THE DERIVATIZATION

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Chemical functionalization of polysaccharides is a very important area of development in the field of carbohydrate polymers [1], as it allows to modulate and often to enhance the physicochemical properties and/or the (bio)activities of the native polysaccharide, or even to confer them new ones [2]. In particular, the covalent conjugation of polysaccharides with functional small molecules through suitable chemical reactions is a field of growing and growing interest. Indeed, polysaccharide conjugates with drugs and other small biomolecules generally possess low toxicity and are compatible with living tissues under many circumstances, thus conferring significant advantages in their clinical applications [1].

The structural characterization of complex biomacromolecules such as polysaccharides, and even more polysaccharide conjugates, is very often not trivial at all, but it is mandatory for investigating structure-activitity relationships. Nonetheless, the successfull covalent conjugation of small molecules to polysaccharides is very often claimed by just recognizing the expected signals in ^{1}H-NMR spectra for the functional groups of the conjugated species. More robust data are not seldom provided by measuring additional NMR spectra such as ^{13}C- and, less frequently, 1D- and/or 2D-diffusion-ordered (DOSY) spectra. The latter are particularly significant for the structural investigation of polysaccharide conjugates with small molecules, as they generally allow to distinguish between the signals related to slow diffusing macromolecules and to low molecular weight species, that are not covalently linked to the former and therefore are able to give a fast diffusion in solution [3].

In this communication some examples are presented of conjugation of polysaccharides with small molecules, that could have been claimed to be successfull by not only ^{1}H-NMR but also 1D-DOSY analysis and instead are demonstrated to be not (or poorly) working by a much more careful structural characterization through a set of homo- and heteronuclear 2D-NMR techniques. Although these are specific cases within the frame of the structural modification of the polysaccharides of interest for our research lines – *i.e.* the production of glycosaminoglycan (GAG)-like species from non-animal sourced polysaccharides [4] – they are presented here to fuel the discussion about the

definition of suitable guidelines for a robust structural determination of derivatized polysaccharides.

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C27 - TUNING CELLULOSE SOLUBILITY AND REGENERATION VIA HOFMEISTER EFFECTS

Interactions in Polysaccharide Systems
Chemistry, Biology & Physics

Tuning Cellulose Solubility and Regeneration via Hofmeister Effects

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The dissolution and regeneration of cellulose are key processes in the development of sustainable bio-based materials.The Hofmeister series, which describes the effects of ions on the stability and solubility of macromolecules in aqueous solutions, offers a tool for modulating cellulose solubility and precipitation dynamics. In this study, we systematically investigate the influence of kosmotropic and chaotropic ions on the cellulose dissolution efficiency in cold alkali systems, phase separation process, and structural properties of regenerated cellulose. The results from turbidity measurements demonstrate that chaotropic ions, such as I^-, can enhance cellulose solubility, while kosmotropic ions, such as K^+, promote faster cellulose aggregation. Structural characterization via X-ray diffraction (XRD) and scanning electron microscopy (SEM) reveals that ion-specific effects govern the final crystallinity and morphology of the regenerated cellulose. These findings provide fundamental insights into ion-mediated cellulose processing and open pathways for tailoring cellulose-based materials through selective salt additions in cold alkali systems.

C28 - ALTERNATIVE SPINNING DOPE STABILIZERS FOR SAFE AND EFFICIENT LYOCELL FIBER PRODUCTION

Chemical, Structural & Functional Characterization
Chemistry, Biology & Physics

ALTERNATIVE SPINNING DOPE STABILIZERS FOR SAFE AND EFFICIENT LYOCELL FIBER PRODUCTION

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The Lyocell process has been established on an industrial scale as a modern, environmentally friendly, sustainable technology for man-made fiber production. The process is based on the dissolution of up to 15 wt% of cellulose in aqueous NMMO (N-methylmorpholine N-oxide) and subsequent regeneration of the cellulose in a water bath via a dry jet-wet spinning.

Despite advantages such as being non-toxic, biodegradable, and over 99% recyclable, NMMO is a strong oxidant, and under real Lyocell conditions, tends to cause undesired side reactions, such as NMMO autocatalytic decomposition, chromophore formation and others. Gallic acid propyl ester (PG) – is currently used as a stabilizer of the Lyocell spinning dope due to its antioxidant properties, ability to trap radicals, formaldehyde, N-(methylene)morpholinium ions, and transition metal ions. However, PG also promotes the formation of additional chromophores (e.g., ellagic acid and the respective ellagoquinone), which leads to significant discoloration and increased contamination of the spinning dope, resulting in reduced fiber quality.

Gallic acid amides have been proposed as an alternative to PG. Owing to the similar molecular structure, they show relatively the same stabilizing effects, but reduced chromophore formation and other side processes due to lower chemical reactivity of the amide bond.

In the current work, various N-mono- and N,N-disubstituted gallic acid amides with different alkyl chain lengths were synthesized using diverse approaches, and characterized by 1D and 2D NMR, HPLC, and FTIR methods. The stabilizing effects and chemical behavior of the obtained amides have been studied under Lyocell conditions in NMMO/H2O and NMMO/H2O/cellulose systems.

Keywords: cellulosic fibers, chromophores, gallamide, Lyocell process, stabilizers
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C29 - A PROFILING APPROACH FOR THE ANALYSIS OF UNSATURATED GALACTURONIC ACID OLIGOSACCHARIDES BY HILIC-PDA(-MS)

Polysaccharide Colloids
Chemistry, Biology & Physics

A PROFILING APPROACH FOR THE ANALYSIS OF UNSATURATED GALACTURONIC ACID OLIGOSACCHARIDES BY HILIC-PDA(-MS)

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Pectins are mainly used in food industry as gelling agents, thickeners, and stabilizers. In addition, pectins show various positive nutritional properties that are also described for pectic oligosaccharides. However, functional and nutritional properties of pectins and pectic oligosaccharides depend on their fine structure. A major structural element of pectins are homogalacturonans. They are composed of α-1,4-linked galacturonic acids, which can be acetylated and/or methylated. Depending on the degree of methylation, unsaturated galacturonic acid oligosaccharides (uGalA-OS) can be released from homogalacturonans by pectin or pectate lyases. For the analysis of these uGalA-OS a profiling approach based on HILIC-PDA(-MS) was developed. This profiling approach can be used to analyze uGalA-OS according to their degree of polymerization after alkaline hydrolysis and, if required, without alkaline hydrolysis according to their number of methyl esters.

Twelve unesterified uGalA-OS with a degree of polymerization of 2-13 were isolated as standard compounds. Chromatographic separation of these uGalA-OS was optimized on an amide-based stationary phase. For detection, the absorption of uGalA-OS at 235 nm was recorded using a PDA. Additional detection with single quadrupole-MS allows to verify the degree of polymerization and the number of methyl esters of uGalA-OS. Determined relative response factors of the unesterified uGalA-OS in relation to acarbose as internal standard substance allow for (semi)quantitative estimation of (un)esterified uGalA-OS within the specified concentration ranges (10/28-100 µM). Thereby, the limit of detection (≤4 µM) and limit of quantification (≤9 µM) increase with increasing degree of polymerization.

The developed profiling approach is useful for various applications. For example, it was possible to analyze the cleavage position of a pectin lyase in homogalacturonans: Citrus pectin with a high degree of methylation was enzymatically degraded with a pectin lyase. Released methyl esterified uGalA-OS were analyzed with HILIC-PDA-MS. The tetramer followed by the penta- and hexamer, each with one unesterified carboxy group, were identified as major uGalA-OS. Surprisingly, additional analysis with orbitrap-MS indicates that the unesterified carboxy group of these three uGalA-OS was located at the non-reducing unsaturated end. Enzymatic treatment of carrot pomace as pectin-rich food by-product with this pectin lyase led to release of uGalA-OS. Unsaturated trigalacturonic acid was identified as major product using the developed profiling approach.

Additionally, uGalA-OS up to a degree of polymerization of twelve were detected. Most of these uGalA-OS had only one or two unesterified carboxy groups.

Overall, a new HILIC-PDA-(MS) profiling approach for the analysis of uGalA-OS was successfully developed and validated. It was demonstrated that this profiling approach is suitable for the analysis of the mode of action of pectin lyases and samples containing uGalA-OS.

This IGF Project (21616N) of the FEI was supported via AiF within the program for promoting the Industrial Collective Research (IGF) of the Federal Ministry of Economic Affairs and Climate Action (BMWK), based on a resolution of the German Parliament.

F1 - CONTENT OF PECTIN, CELLULOSE AND DIETARY FIBRE IN FRUIT AND VEGETABLES AVAILABLE ON MARKET

Dietary Fiber
Food & Nutrition

CONTENT of Pectin, Cellulose and Dietary Fibre in Fruit and vegetables available on market

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Fruits and vegetables are a valuable source of pectin, cellulose and dietary fibre. The content of individual components depends on many factors, including species, variety and physiological condition. Promoting the consumption of plant products rich in dietary fibre and searching for new alternative sources of pectin and cellulose are extremely important for a wide range of stakeholders, both consumers and entrepreneurs interested in developing new products consistent with the principle of sustainable development. In order to improve public awareness of the consumption of dietary fibre-rich fruit and vegetables and to promote the use of this raw material as a source of functional polysaccharides, pectin, cellulose and fibre content were determined in more than thirty different commodities of fruit and vegetables available on the local market in Poland. The database created was used in the new FibreApp application for mobile devices. The application provides the content of these components based on the image of the object.

Acknowledgement

Publication co-financed from the state budget under the program of the Minister of Education and Science called "Science for Society II" project number NdS-II/SP/0258/2023/01 amount of funding 1 000 000 PLN, total value of the project 1 000 000 PLN.

F2 - Rhamnogalactan and Fucogalactan of mushrooms: The cholesterol-lowering agents

Functional Foods
Food & Nutrition

Rhamnogalactan and fucogalactan of mushrooms: the cholesterol-lowering agents

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Polysaccharides are the main component present in mushrooms' dry matter and their cholesterol-lowering properties have been recognized in several *in vitro* and *in vivo* studies [1,2]. However, the relationships between the structure of mushroom polysaccharides and their hypocholesterolemic effects are still undisclosed.

In this work, hot water-soluble polysaccharides present in *Lactarius deliciosus* and *Macrolepiota procera* were extracted and the aqueous extracts were further fractionated with graded ethanol precipitation. Polysaccharide-rich fractions (93 – 53%), insoluble in 50% and 60% of ethanol, are mainly composed of galactose and glucose in both mushroom species, rhamnose (*L. deliciosus*) and fucose (*M. procera*). The glycosidic linkages analysis of the partially methylated alditol acetate showed the presence of linear (1→6)-liked galactose (52 – 6% mol) and (1→2,6)-linked galactose (16 – 4% mol). The Et50 fraction of *L. deliciosus* showed the presence of a rhamnogalactan, with terminally-linked rhamnose (14 – 3% mol), while Et50 and Et60 fractions from *M. procera* showed the presence of a fucogalactan, with terminally-linked fucose (7 – 6% mol). The average polymerization degree of rhamnogalactan and fucogalactan varies between 7 – 26 and 10 – 11, respectively.

Assessment of cholesterol lowering activity of rhamnogalactan from *L. deliciosus* were tested using an *in vitro* intestinal simplified model [3]. The solubility of cholesterol films was measured by GC-MS and showed that cholesterol accessibility decreased by 90 – 73%. Bile salts sequestration capacity was quantified using ^{1}H NMR and showed a decrease of 38 – 10%.

The rhamnogalactan with lower average polymerization degree decreases the cholesterol solubility by interaction with cholesterol and bile salts sequestration, demonstrating the structure-function relationship between mushroom polysaccharide and hypocholesterolemic properties.

Acknowledgements: Project Safe2Taste (MTS/BRB/0056/2020 DOI 10.54499/MTS/BRB/0056/2020) and LAQV-REQUIMTE (UID/50006 -Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos). Helena Laronha thanks FCT/MCTES and ESF through NORTE 2020 (Programa Operacional Região Norte) for her PhD grant (Ref. 2022.13262.BD). Elisabete Coelho thanks Portuguese national funds (OE), through FCT, I.P., in the

scope of the framework contract foreseen in the numbers 4, 5 and 6 of the article 23, of the Decree-Law 57/2016, of August 29, changed by Law 57/2017, of July 19 (CDL-CTTRI-88-ARH/2018 - REF. 049-88-ARH/2018). Filipe Coreta-Gomes acknowledge the research contract funding due to LAQV-REQUIMTE (UIDB/50006/2020 DOI 10.54499/UIDB/50006/2020) project. **Funding:** Supported by Safe2Taste (MTS/BRB/0056/2020 DOI 10.54499/MTS/BRB/0056/2020), FightSterol (PTDC/QUI-OUT/29373/2017) funded by FCT/MCTES through national funds and, where applicable, co-financed by the FEDER, within the PT2020 Partnership Agreement and Compete 2020. The authors also acknowledge the funding through LAQV/REQUIMTE (LA/P/0008/2020 DOI 10.54499/LA/P/0008/2020, UIDB/50006/2020 DOI 10.54499/UIDB/50006/2020, UIDP/50006/2020 DOI 10.54499/UIDP/50006/2020 , UID/50006 -Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos).

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F3 - Replacement of sugar in ice cream by using dietary fiber from food by-products

Dietary Fiber
Food & Nutrition

Replacement of sugar in ice cream by using Dietary fiber from food by-products

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In most European countries, an average of at least 6 kg of ice cream per person are consumed every year. This makes ice cream one of the favorite confectionery products, but both high sugar and calorie contents contribute to its nutritional disadvantages. In addition to the sweet flavor, sugar is important for the technological properties. It has an influence on the texture and creaminess and cannot easily be reduced without sensory changes. Soluble dietary fiber (SDF) and low molecular weight soluble dietary fiber (LMWSDF) are suitable substitutes due to their chemical structures. By-products from the food industry are good feedstocks to generate suitable dietary fiber samples. Carrot pomace, lupin inner fiber, and blackcurrant seeds were selected for this purpose as they have different fiber profiles and thus offer the possibility of generating samples with different properties. The aim was to increase the content of SDF and LMWSDF in these fiber samples using mechanic and enzymatic processes and incorporate SDF and LMWSDF in ice cream as sugar replacer. Already optimized treatment conditions for the carrot and lupin samples were adopted from a previous study, while the effects of the currant sample treatments were investigated in detail. Due to the high contents of mannans and cellulose, the enzymatic treatment was carried out with a mannanase and a cellulase.

Mechanically and enzymatically processed by-products were chemically characterized and studied for their technofunctional properties in ice cream. Following treatment, the mannan-rich blackcurrant dietary fiber sample had a high content of LMWSDF and mannobiose, while the SDF content was low. In contrast, the carrot and lupin dietary fiber samples contained higher amounts of LMWSDF as well as higher levels of SDF. Both, carrots and lupins, are pectin-rich raw materials, but galacturonic acid based polymers dominated in the carrot sample and galactans in the lupin sample. In addition to different polysaccharide profiles, the molecular weight distributions of the SDF differed. SDF of the lupin dietary fiber sample showed the highest molecular weights and those of the blackcurrant dietary fiber sample the lowest. For comparison with the dietary fiber samples generated from food by-products, commercial dietary fiber samples of galactooligosaccharides and inulin with different degrees of polymerization were characterized and also incorporated into the ice cream. The fiber-enriched ice cream was examined with regard to technological and sensory parameters. The use of dietary fiber samples with SDF of higher molecular weights resulted in a higher viscosity, which was perceived as a higher creaminess. A dietary fiber content of more than

3 g per 100 g of ice cream was analytically determined, justifying a dietary fiber claim according to the regulation (EC) No 1924/2006 on nutrition and health claims made on foods. Thus, it was possible to reduce the sugar content in ice cream by using fiber samples from food by-products without affecting consumer-relevant parameters.

F4 - Impact of molar mass and delivery form on the fecal fermentation of pectin

Dietary Fiber
Food & Nutrition

Impact of Molar Mass and Delivery Form on the Fecal Fermentation of Pectin

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Dietary fibers (DFs) are carbohydrate polymers that resist hydrolytic digestion in the human gastrointestinal tract (GIT) but are fermented by our gut microbiota—an essential microbial community that influences the individual's nutrient absorption, health, and disease prevention [1]. Among DFs, pectin is abundant in plant products, and it is widely used both in the food industry and the pharmaceutical sector [2]. Fermentation of DFs is influenced by various aspects, such as monomer composition, molecular weight, particle size, and concentration; therefore, real food systems present a complex and heterogeneous matrix that complicates direct analysis [3].

The effect of molar masses on the fecal fermentation of pectin has been investigated as well as the effect of the pectin delivered as a gel or dispersion. Our analysis employs in vitro human fecal fermentation, size exclusion chromatography with multiangle light scattering (SEC-MALS), monosaccharide analysis, and dynamic light scattering (DLS). The results show increased total SCFA production upon fermentation of pectin gel as compared to pectin dispersion. This is possibly related to the increased local concentration of the pectin immersed in the gel as compared to dispersion, however, we cannot at this moment exclude the impact on total SCFA from the gelation method.

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F5 - Feasibility of carrageenan structures suitable for meat alternative proteic foods

Food Additives, Consistency & Texture
Food & Nutrition

Feasibility of carrageenan strutures suitable for Meat alternative proteic foods

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Carrageenan refers to a group of sulfated galactans derived from red algae. These polysaccharides are commonly used to enhance the textural properties of meat products and their analogues. Meat substitutes typically depend on protein gelation or other hydrocolloids to achieve the necessary firmness and replicate the texture of real meat. While vegetarian formulations can include animal-derived ingredients such as egg whites for their gelling properties, vegan alternatives require plant-based proteins supported by carbohydrate-based hydrocolloids capable of forming strong gels.

This study examined the characteristics of carrageenans suitable for incorporation into two distinct protein-based food formulations: cooked ham and a meat-free analogue. In the cooked ham formulation, a commercially available carrageenan was used to improve water-holding capacity by forming a gel that binds water, reduces shrinkage, and increases yield. Its carbohydrate composition included 53 mol% galactose and 46 mol% 3,6-anhydrogalactose, with one in every four residues being sulfated, accounting for a total carbohydrate content of 47%. Texture Profile Analysis of the cooked ham model revealed that carrageenan addition significantly increased hardness from 83.1 N to 97.0 N and chewiness from 2474 N to 3239 N compared to the carrageenan-free formulation. These increases in hardness and chewiness align with gel formation, resulting in a more sliceable product.

For the meat analogue, gel emulsion formation was achieved using a commercial carrageenan-rich ingredient composed of 64% carbohydrates (43 mol% galactose, 33 mol% 3,6-anhydrogalactose, and 24 mol% glucose), with a sulfation level of 22 mol%. The resulting formulation produced a firm product with desirable textural properties, comparable to a vegetarian version using egg white as a gelling agent. Carrageenan presents as an interesting gel hydrocolloid in meat products and their analogues formulations.

Acknowledgments: The authors acknowledge LAQV-REQUIMTE (UID/50006 -Laboratório Associado para a Química Verde - Tecnologias e Processos Limpos) and CICECO-Aveiro Institute

of Materials, UIDB/50011/2020 (DOI 10.54499/UIDB/50011/2020), UIDP/50011/2020 (DOI 10.54499/UIDP/50011/2020) & LA/P/0006/2020 (DOI 10.54499/LA/P/0006/2020), funded by FCT/MCTES through national funds. B. A. C. Ferreira and P.A.R.F. acknowledge the FCT grant (ref. 2023.03733.BDANA) and research contract funding (project Agenda VIIAFOOD), respectively. Cláudia Nunes thanks FCT for funding through program DL 57/2016 – Norma transitória (Ref. 049 88 ARH/2018 and DL 57/2016/CP1482/CT0031).

Funding: This research was funded by PT national funds (FCT/MCTES, Fundação para a Ciência e Tecnologia and Ministério da Ciência, Tecnologia e Ensino Superior) and the European Union (NextGenerationEU) through the project Agenda VIIAFOOD - Plataforma de Valorização, Industrialização e Inovação comercial para o AgroAlimentar (n.º C644929456-00000040). This work was developed within the scope of project “Missão Interface” funded by the Portuguese Recovery and Resilience Plan (PRR) and the Next Generation EU European Fund.

F6 - Effect of Extraction pH on Rheological Properties of Pectin Hydrogels Extracted from Industrial Sugar Production Sidestreams

Dietary Fiber
Food & Nutrition

Effect of Extraction pH on Rheological Properties of Pectin Hydrogels Extracted from Industrial Sugar Production Sidestreams

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Sugar beet bagasse comprises a significant portion of waste generated from industrial production of beet sugar. This by-product, a fibrous residue which remains after sugar extraction, is rich in polysaccharides, of which up to 30% of the total content is made up of pectin [1]. The complex structure of the pectin exhibits distinct functionality and nutritional properties, making it an ideal candidate for the valorisation of the bagasse through development of new materials and novel food ingredients. Sugar beet pectin primarily consists of two major regions, a linear region dubbed homogalacturanan and a heavily branched region known as rhamnogalacturanan-I (RG-I). These regions provide the overall polysaccharide with unique properties based on the distribution of the regions and functional groups present. One substituent of particular interest, found within the RG-I structure is ferulic acid, a phenolic species which exhibits antioxidant properties while simultaneously allowing to form enzyme-catalysed diferulic acid crosslinks [2]. This reaction serves a platform for the generation of covalently-linked structural networks with high water retention abilities i.e. hydrogels. For the purpose of hydrogel formation, the selection of an extraction method for sugar beet pectins that preserves these phenolic substitutions is vital. Subcritical water extraction, which utilises water at high pressure and temperature, has been shown to be particularly well-suited for this purpose. However, the release of acetyl substituents can lead to acidification of the extraction solvent, potentially leading to hydrolysis of the polysaccharides [3]. Therefore, in this project we have investigated the impact of extraction pH and time on sugar beet pectin structure and composition. The differently extracted pectins were then used to form hydrogels whose gelation point and rheological properties have been investigated. The results have shown a stark difference between acidic and neutral conditions during extraction, with the acidic extraction conditions granting hydrogels with higher storage and loss modulus. These results indicate that the extraction conditions result in different molecular structures of the pectic regions, which in turn result in different rheological profiles for the final gels. The production of hydrogels with tuneable physical properties, sourced from sugar production side streams, can provide opportunities for the development novel food ingredients with prebiotic and antioxidant properties, while upscaling existing underutilised side streams.

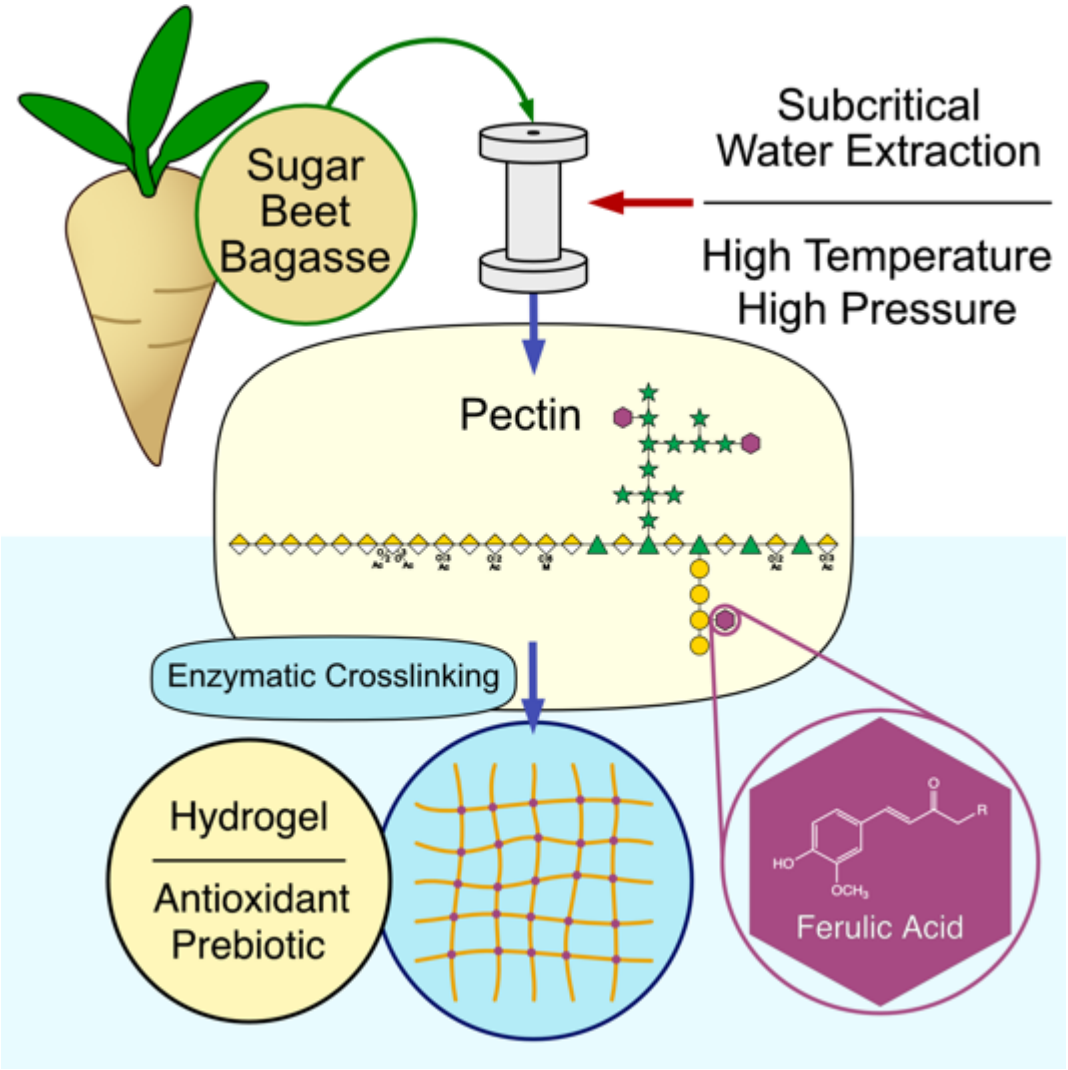

Figure: Hydrogel formation process overview

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F7 - Cellulose-based microcapsules for the protection of active ingredients in acorn-based bread formulations

Functional Foods
Food & Nutrition

Cellulose-based microcapsules for the protection of active ingredients in acorn-based bread formulations

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Bread is one of the most popular foods in the world, with a strong presence in the daily lives of populations due to easy access to this food. On the other hand, the consumers' conscientization of the need to maintain high health standards, has led to the development of the so-called “functional foods”. In this sense, the role of essential oils and probiotic microorganisms is seen as essential, because of their good biological activities and beneficial impact on human health. However, to keep the active ingredients stable, these should be protected by methods which prevent oils from evaporating and oxidation, and probiotics from loss of viability. Encapsulation (microencapsulation) is a suitable and interesting method for the protection of active ingredients in bread products. To do so, some bio-based polymers were selected to prepare microcapsules able to protect the active ingredients during the bread preparation process, mainly during the baking. Bacterial cellulose (BC) obtained from vinegar process, the “Mother of vinegar” and cellulose derivatives, such as methylcellulose, were selected to prepare microcapsules. Due to its inherent high molecular weight (Mw) and lack of solubility, BC needs to be pre-processed using suitable processes, such as enzymatic pre-treatment, ultrasounds or high-pressure homogenization (mechanical treatments). The prepared microparticles, using different polymers and mixtures, were obtained by different techniques such as ultrasonication, high-speed homogenization, high-pressure homogenization, and spray drying. The effect of composition and preparation methods on the protection of active ingredients was explored, and the prepared particles were characterized.

Acknowledgements

The authors want to acknowledge Fundação la Caixa and FCT for the financial support through the project “Plantas aromáticas do Alentejo, probióticos e farinha de bolota no desenvolvimento de pão funcional” (PD23-0025). FCT is also acknowledged for its financial support through the Strategic Research Centre Project UIDB/00102/2020 and UIDB/05183/2020.

F8 - ANTIOXIDANT AND ANTIFUNGAL POTENTIAL OF ESSENTIAL OILS FROM AROMATIC PLANTS IN PORTUGAL : INSIGHTS FROM THE ALBREAD PROJECT

Functional Foods
Food & Nutrition

ANTIOXIDANT AND ANTIFUNGAL POTENTIAL OF ESSENTIAL OILS FROM AROMATIC PLANTS IN PORTUGAL : INSIGHTS FROM THE ALBREAD PROJECT

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Essential oils (EOs), extracted from various parts of aromatic plants, have been used for centuries for their therapeutic properties. These natural compounds continue to play a prominent role in folk medicine across diverse cultures, thanks to their wide-ranging medicinal benefits, including antioxidant, anti-inflammatory, analgesic, anticancer, liver-protective, and neuroprotective effects, among others. As part of the "Albread" project, supported by the Promove 2023 competition and titled "Aromatic plants from Alentejo, probiotics, and acorn flour in the development of functional bread," this study explores the antioxidant and antifungal potential of OEs sourced from companies in the Alentejo and Algarve regions of Portugal.

A total of 21 OEs were evaluated for their antioxidant properties using three different methods: DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging, ABTS (2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) radical scavenging, and the β-carotene/linoleic acid bleaching assay. The results revealed distinct antioxidant profiles across the EOs, with qualitative agreement among the methods used. Additionally, the EOs were tested for their antifungal activity. The chemical composition of the EOs was analyzed by gas chromatography-mass spectrometry (GC-MS) to identify and quantify key components, establishing a tentative link between the composition of the oils and their antioxidant and antifungal capacities.

The authors want to acknowledge Fundação la Caixa and FCT for the financial support through the

project “Plantas aromáticas do Alentejo, probióticos e farinha de bolota no desenvolvimento de pão funcional” (PD23-0025).

M1 - ON THE TRIBOELECTRIC PROPERTIES OF REGENERATED CELLULOSE FILMS COMPOSITED WITH 0D, 1D, AND 2D CARBON ALLOTROPES

Energy Applications
Materials & Engineering

on the triboelectric properties of regenerated cellulose films composited with 0D, 1D, and 2D carbon allotropes

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Triboelectric nanogenerators (TENGs) are a sustainable technology for converting mechanical energy from motion, vibrations, or friction into electrical energy via contact electrification and electrostatic induction [1]. By pairing materials with different electron affinities, TENGs can harvest energy to power small-scale electronics and sensors. While much of the research in this field has focused on synthetic, oil-based polymers, polysaccharides such as cellulose are gaining attention as sustainable alternatives.

Regenerated cellulose (R-cellulose) films were proven to be suitable tribomaterial due to their high positive triboelectric charge density [2]. To increase the triboelectric performance, carbon nanomaterials (CN) can be added to improve the charge transfer through the films, and CN can also act as electron donors [3]. This is a comprehensive study on the triboelectric performance of R-cellulose films composited with different carbon allotropes, including graphene (2D), CNT (1D), and nanodiamond (0D).

Briefly, carbon nanoparticles were dispersed in a urea/LiOH aqueous solution using a high-shear exfoliation mixer, and the cellulose was dissolved in a similar solution via the cold-alkali method. The cast films prepared from this mixture were regenerated in an ethanol bath, followed by washing in MilliQ water [2]. The microstructure and composition of the composite materials were confirmed by spectroscopic techniques, X-ray diffraction analysis, and electron microscopy. The surface morphology and roughness of the samples were examined by the atomic force microscopy (AFM).

Figure 1 depicts the power output versus nanoparticle content. Triboelectric performance testing revealed that the addition of graphene as well as CNTs increases the power output up to a certain nanoparticle content in the composite, after which it slightly decreases- possibly due to reaching the electrical percolation threshold. The addition of nanodiamonds, which are electrically insulating but highly dielectric, also increases the power output of the TENG. Moreover, we tested CNTs with three different functionalizations to investigate the effect of functional groups on the triboelectric performance of the cellulose composites.

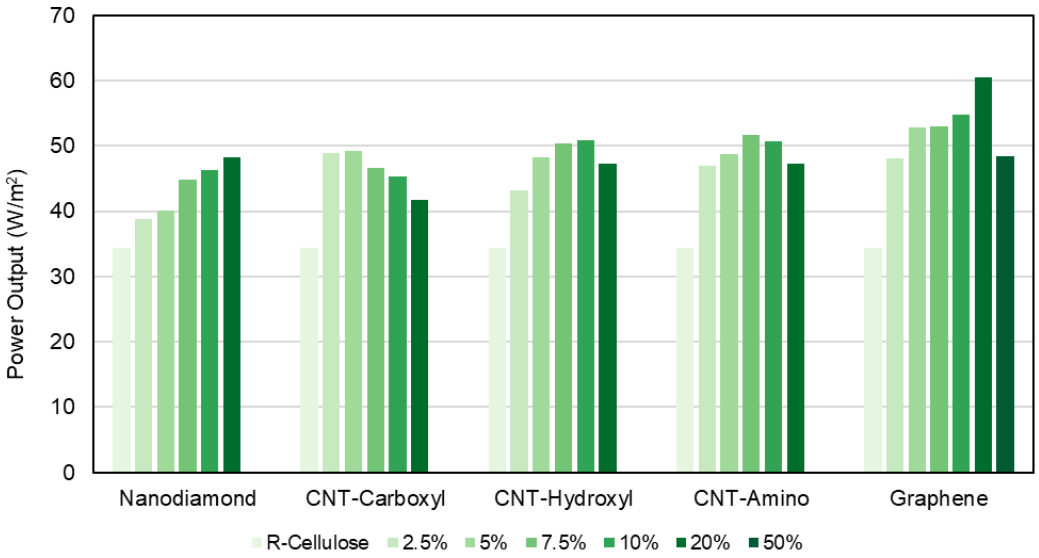

Figure 1. Power output of R-Cellulose composites with different carbon allotropes (TENG mode: contact-separation, Counter layer: PTFE)

[1] Wang, Z. L. et al., *ACS Nano* **2013**, *11,* 9533-9557

[2] Dahlström, C. et al., *Cellulose* **2024**, *31,* 2047–2061

[3] Zhang, R. et al., *EcoMat* **2020**, *2,* e12062

M2 - Cellulose mineralization via carbonation: a route for Carbon Capture and Utilization

Sustainable Materials/Circular Economy
Materials & Engineering

Cellulose mineralization via carbonation: a route for Carbon Capture and Utilization

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Mineralizing cellulose via carbonation is an emerging strategy for developing sustainable materials while capturing and utilizing CO_2. This process enables the transformation of lignocellulosic biomass into hybrid organic-inorganic materials by facilitating CO_2 absorption in alkaline solutions, leading to the formation of reactive carbonates, bicarbonates, and carbamates. In the presence of calcium and magnesium, thermodynamically stable and environmentally benign precipitates form within cellulose fiber networks, yielding durable, functional composites.

This fast and scalable method has broad applications in construction, biomedical scaffolds, and artificial coral stone formation, offering a novel pathway for CO_2 sequestration and biomass valorization. Early studies demonstrated the feasibility of this approach using dissolved microcrystalline cellulose (MCC), highlighting its potential for sustainable material innovation [1].

In current work, we are further advancing mineralized fiber development from (ligno)cellulosic sources, focusing on optimizing CO_2 absorption, enhancing mineralization efficiency, and expanding applications for large-scale implementation. Our work contributes to the advancement of accelerated Carbon Capture and Utilization (CCU) technologies by integrating renewable biomass with mineral carbonation to create value added and eco-friendly materials.

[1] Reyes, G.; Vega-Coloma, M.; Antonova, A.; Ajdary, R.; Jonveaux, S.; Flanigan, C., Lautenbacher, N.; Rojas, J.O. *Adv. Mater.* **2023**, 35, 2209327

M3 - DESIGN OF A ROTATIONAL FILTRATION SYSTEM TO EVALUATE TRIBOELECTRIC EFFECTS FOR ENHANCED CELLULOSE-BASED AIR FILTRATION

Energy Applications
Materials & Engineering

Design of a Rotational Filtration System to Evaluate Triboelectric effects for Enhanced Cellulose-based Air Filtration

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Air pollution constitutes one of the most significant global public health dilemmas, emphasizing the critical necessity for enhanced air filtration methodologies [1]. Triboelectric filtration is a promising approach where airborne particle retention is improved through static charging of the filter material via frictional events between different material surfaces. By incorporating cellulose as a tribopositive filter medium, an efficient and sustainable particle filter solution is expected. In this study, we introduce a specially designed experimental platform to evaluate how triboelectric effects make different materials perform in dynamic air filtration environments. The device includes an air inlet for particle-laden airflow, a fixed triboelectric filtering layer, and a counter-rotating layer with an adjustable gap beneath it. The movement between the layers is intended to promote interactions that help to capture particles more efficiently through the triboelectric effect [2].

The setup features several key elements: an adjustable gap between the triboelectric layer and the counter-layer, a modular system for mounting materials to facilitate comparative studies, and an outlet connected to a sensing unit that measures the filtration efficiency of particles after interaction. This design allows an in-depth investigation into how different material combinations and process parameters impact particle capture.

In conclusion, this system offers a unique framework for examining the dynamic interactions of triboelectric materials within the realm of air purification, which may facilitate the advancement of more effective air filtration technologies [3].

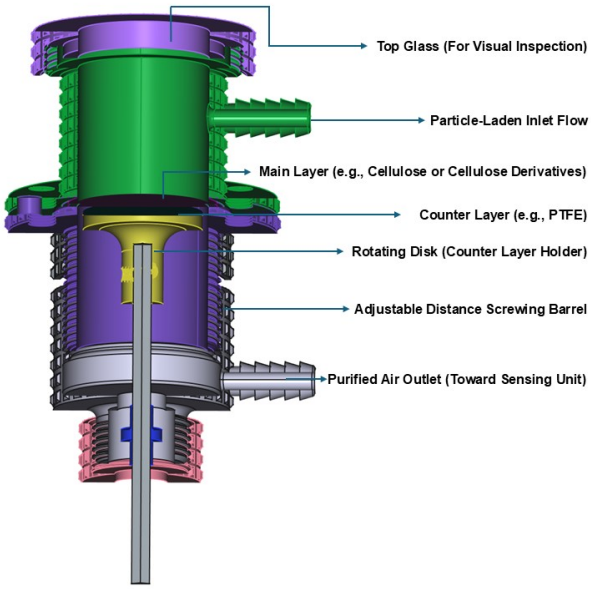

Figure 1. Schematic illustration of the triboelectric air filtration testing device.

[1] Haug, T.; Søstrand, P.; Løvik, M.; Langård, S., *The Lancet* **2001**, *357*, 70.

[2] Shi, W., Wang, X. ; Diao, W. ; Liu, G.; Cao, Y., *Nano Energy* **2025**, *137*, 110758.

[3] Li, C.L.; Song, W.Z. ; Sun, D.J. ; Zhang, M.; Zhang, J.; Chen, Y.Q.; Ramakrishna, S.; Long, Y.Z., *Chem. Eng. J.* **2023**, *452*, 139428.

M4 - A PRACTICAL METHOD FOR PRODUCTION OF DEFINED LOW MOLECULAR WEIGHT CELLULOSE FRACTIONS

Sustainable Materials/Circular Economy
Materials & Engineering

A Practical method for production of defined low molecular weight cellulose fractions

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Buffiere at al [1] have identified a 'degree of polymerisation availability gap' in the provision of technical celluloses, for scientific and innovation studies. They propose sub-critical water extraction, as a scalable method for production of defined fractions. However, this method still requires high capital expendature for production of materials, somewhat limiting innovation. The state of the art utilises 'superphosphoric acid' for production of fractions although space-time yields are still rather low using this method.

Recently we developed an expedient method for production of samples, based on the 'amorphisation', controlled oxidation and b-elimination sequence, which allows for some flexibility in controlling molecular weight, polydispersity and to afford high yields of water-insoluble fractions (> DP_N 6).

This abstract will detail the methodology and analytics, leading to this proof of concept. It is our intention to present data to demonstrate the flexibility and expediency of this method, for further innovation studies.

[1] Buffiere J, Ahvenainen P, Borrega M, Svedström K, Sixta, H. Supercritical water hydrolysis: a green pathway for producing low-molecular-weight cellulose. *Green Chem.*, **2016**,*18,* 6516-6525. https://doi.org/10.1039/C6GC02544G

M5 - All-cellulose hydrogel with ultrahigh stretchability exceeding 40000%

Nanostructured Materials
Materials & Engineering

All-cellulose hydrogel with ultrahigh stretchability exceeding 40000%

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While cellulose-based stretchable hydrogels have been extensively explored in recent years, all-cellulose hydrogels continue to face the limitation of low stretchability (less than 250 %). Herein, for the first time, we fabricate an all-cellulose hydrogel with ultrahigh stretchability that can exceed 40000 % strain. By ring opening reaction on cellulose anhydroglucose unit rings, secondary hydroxyls are converted to primary hydroxyls, enabling enhanced chain flexibility, and facilitating the formation of abundant . As a result, the obtained hydrogel displays remarkable characteristics, including record-high stretchability (44200 %), rapid self-healing property (within seconds), and the unique ability to form cellulose fiber. With simple drawing, a smooth and flexible cellulose fiber can be obtained, demonstrating good processability and a high of 226 MPa. Furthermore, the all-cellulose hydrogel can function as a human motion sensor and electrocardiogram electrode for monitoring physiological signals. This simple yet highly effective method will not only propel the advancement of ultrastretchable all-cellulose hydrogels but also create new possibilities for wearable device applications.

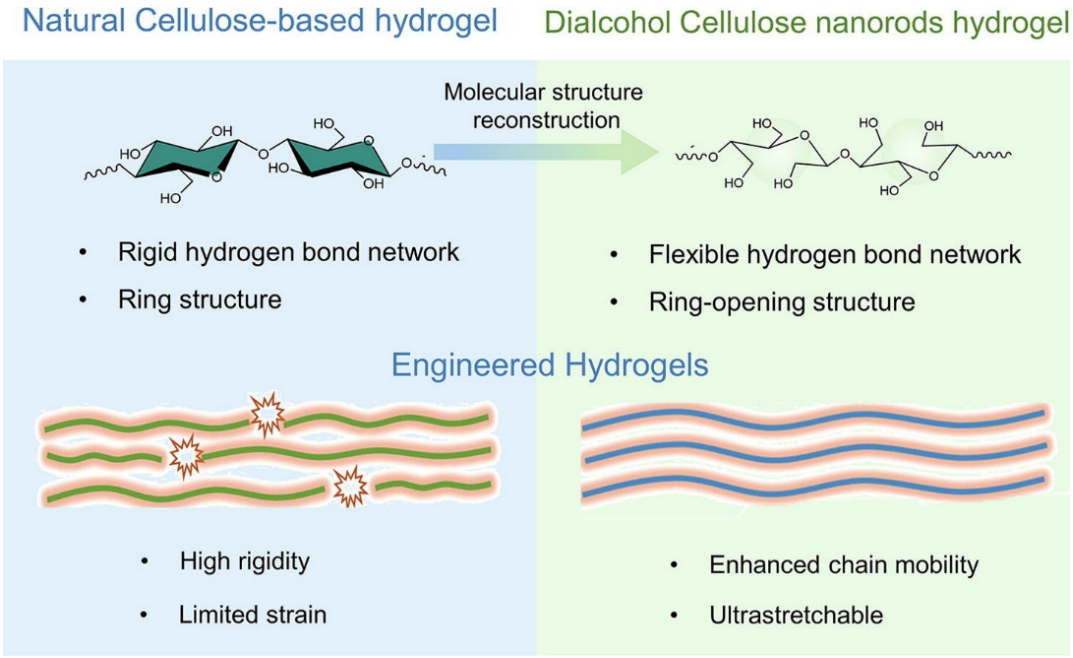

Figure 1. Maximum one figure or table

M6 - THE LYOCELL PROCESS AS A GREAT POSSIBILITY TO RECYCLE CELLULISIC FIBERS AND FABRICS

Sustainable Materials/Circular Economy
Materials & Engineering

The Lyoc ell Process as a great possibility to recycle cellulisic fibers and Fabrics

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The majority of textiles are made from either synthetic polyesters or cellulosic fibers. From these cellulosic fibers in turn, cotton plays the most important role. However, cotton on the one hand is quite water consuming and on the other hand their growth areas are limited. There is a gap between cellulosic fiber demand and supply, which is called cellulose gap. Further problems like an increase of world population and fast fashion enhance this gap. The use of man-made cellulosic fibers (MMCFs) will be the only possibility to close the gap and to help to overcome the textile based problems.

Hereby, the Lyocell process offers a great possibility to obtain fibers from wood, agricultural waste or even cotton waste products. Especially, the use of annual plants like hemp can play an important role as feedstock and the resulting tenacity values of the spun fibers are particularly high. Within the Lyocell process it is also possible to recycle cellulosic shredded fibers or textiles by another dissolution and spinning process. Through the relatively mild process, the degree of polymerization is decreasing only to a small extent and the recycled fibers still have decent strength values.

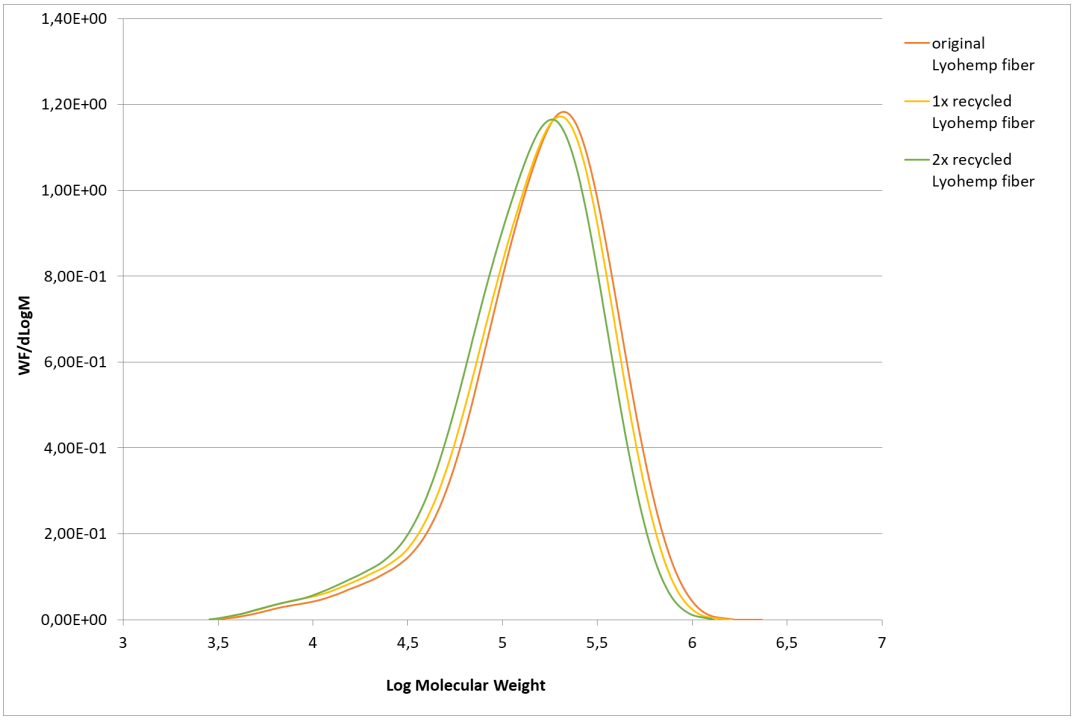

Figure 1 : Determined molecular weight distributions of spun fiber samples.

M7 - TURNING WASTE INTO VALUE: RETHINKING CHITIN ISOLATION EXTRACTION FOR A GREENER WORLD

Other
Materials & Engineering

Turning Waste into Value: Rethinking Chitin Isolation Extraction for a Greener World

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Chitin, a biopolymer found in arthropod shells and fungi, has immense potential as a sustainable material. However, current extraction methods are energy-intensive and environmentally damaging, necessitating eco-friendly alternatives. As demand for sustainable materials rises, this study aims to explore greener chitin extraction methods, focusing on enzymatic, microbial, and low-energy mechanical techniques to improve efficiency and reduce environmental impact. We tested enzymatic extraction using chitinases, microbial fermentation with Bacillus species, and low-energy mechanical methods like ultrasound-assisted and supercritical CO_2 extraction to isolate chitin from waste materials (Figure 1). Enzymatic extraction yielded the highest chitin purity and yield, while microbial fermentation and mechanical methods also showed potential, with life cycle analysis revealing a significant reduction in energy consumption and chemical waste compared to traditional methods. The results demonstrate that combining enzymatic and microbial techniques with low-energy methods offers a sustainable alternative to chemical extraction, though further optimization is needed for large-scale applications. This study on sustainable chitin isolation aligns with SDG 12 (Responsible Consumption and Production) by promoting eco-friendly extraction methods that reduce waste and minimize environmental impact.

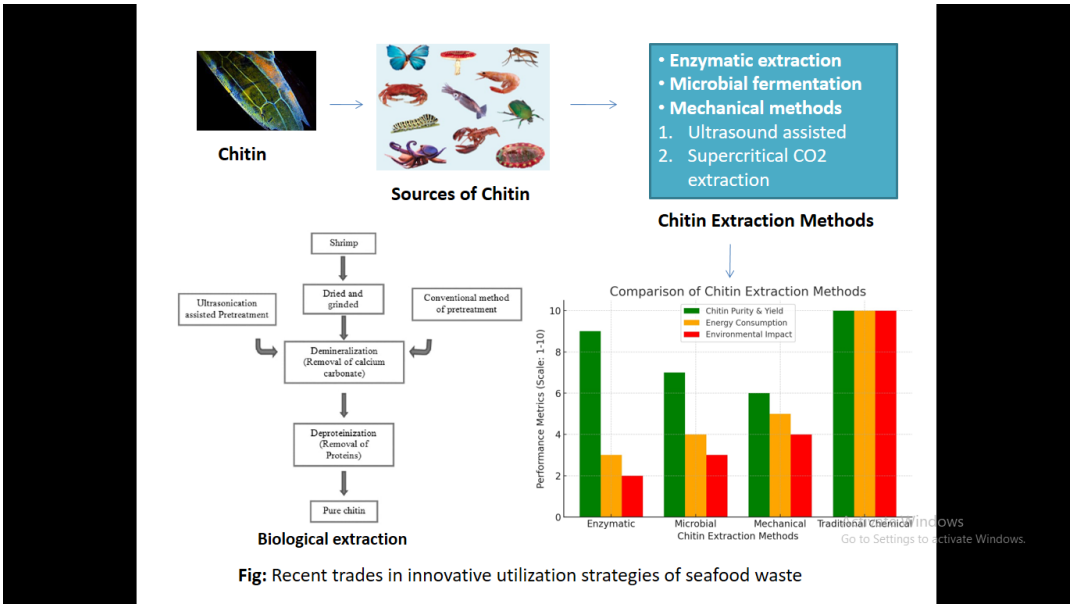

Fig: Recent trades in innovative utilization strategies of seafood waste

Figure 1. Flow Sheet of chitin extraction

M8 - Wood-based sugar-derived adhesives

Polysaccharide-Based Adhesives & Sealants
Materials & Engineering

Wood-BaSED sugar-derived adhesives

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Sugar-based chemicals are considered as building blocks for a wide range of products, from additives to plastics to cosmetics, and are generally recognised as safe (GRAS) materials. Deriving sugars from biomass, specifically from side- and waste-streams of the biomass industry, allows to expand the utilisation level of related materials and decrease the carbon footprint of the industry, while also giving a push to a new technologies and applications.

Sugar-based glues have been reported previously as a suitable binders for plywood, with good durability and water-resistance. [1] In this work we produce a number of wood-derived sugar-based crosslinkable adhesive formulations and test them in application to different materials on a lab-scale. The goal is to produce adhesives, that would be safe for use as food grade materials.

[1] Li, Ch.; Lei, H.; Wu, Zh.; Xi, X.; Du, G.; Pizzi, A. *ACS Appl. Mater. Interfaces* **2022**, *14*, 20, 23859

M9 - Valorisation of Lupine stalk fibres for Foam-formed Acoustic absorbers

Sustainable Materials/Circular Economy
Materials & Engineering

Valorisation of lupinE stalk fibres for Foam-formed acoustic absorbers

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Large-leaved lupine (*Lupinus polyphyllus*) is classified as an invasive plant in Europe and measures are taken by Nordic countries to cut the plants down to reduce growth in the next year [1]. The lupine stalks are a potential lignocellulosic feedstook for the development of biobased materials. Such a material are biobased sound absorber which could be an alternative for commonly used mineralwool. Foam-formed acoustic absorber from wood pulp have exceeded glasswool in their performance while sequestering carbon [2]. Alternative biomass like lupine stalks can have a similar outcome and reduces, as an annual plant, the use of wood pulp.

In this work lupine stalks were soda pulped with a chemical charge of 20 % at 100 °C for 60 minutes followed by mechanical defibration with a Hollander to obtain fibres. The fibres were foam-formed with a fibre consistency of 2.5 % and sodium dodecyl sulphate (SDS) at 10 000 rpm. After the foam doubled its volume the foam was poured into an acrylic pipe arranged on a 0.16 mm stainless steel mesh to drain the water. The selfstanding foams were dried in a ventilated oven at 45 °C for 18 hours. Samples with a fibre dry mass of 5 g, 6.25 g and 7.5 g were produced to achive foam heights between 21 and 25 mm. The foams had a calculated density of 64 to 71 kg/m^3, a porosity of about 96 % and an average air flow resistivity of 51200 Pa*s/m^2. The acoustic absorption was measured with a 29 mm impedance tube giving the highest absorption coefficient of 0.98 at 1800 Hz for a sample height of 21 mm. With increasing sample height the heighest absorption coefficient shifts to lower frequencies, with the 25 mm samples absorbing 95 % of the sound at 1200 Hz.

The foam-foamed lupine stalk pulp foams allow sound to penetrate easily due to the high porosity, with the tortuosity value indicating that the sound wave path has minimal deviation, but the airflow resistivity increases sound absorption in the mid frequency range (250 to 2000 Hz) due to significant frictional losses, as shown by the results of the impedance tube measurements. These results are close to those reported for wood foams [2], while having lower sample heights, thus indicating

promising performance. Overall, we showcase that it is possible to pulp and utilize invasive lupine stalks as an alternative biobased sound absorbing material. In the future other underutilised annual plants will be researched for their suitability as alternatives to wood fibres, consequently reducing the wood logging.

[1] Ramula, S. (2020). Annual mowing has the potential to reduce the invasion of herbaceous Lupinus polyphyllus. Biological Invasions, 22(10), 3163-3173.

[2] Cucharero, J., Ceccherini, S., Maloney, T., Lokki, T., & Hänninen, T. (2021). Sound absorption properties of wood-based pulp fibre foams. *Cellulose*, *28*, 4267-4279.

M10 - TUNNNG HYDROPHILICITY OF PECTIN AEROGELS VIA HETEROGENEOUS AMIDATION

Nanostructured Materials
Materials & Engineering

Tunnng hydrophilicity of pectin Aerogels via heterogeneous amidation

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Aerogels are solid materials with nanometer-scale pores showing interesting properties (e.g., high porosity, low density, and high specific surface area) for a range of applications. The field of aerogels based on natural resources, such as polysaccharides, is gaining more and more attention due to the need for sustainable alternatives to conventional, non-renewable counterparts. Among bio-based aerogels, pectin aerogels possess a density of around 0.1 g^{-1} cm^{-3} and a very fine network with meso- and small macropores.[1] Thanks to these properties, the thermal conductivity of pectin aerogels is below that of air (< 0.025 W m^{-1} K^{-1}) making these materials perfect candidates for thermal insulation applications.[2] However, pectin aerogels are highly hygroscopic: they adsorb moisture from the air leading to network collapse and loss of the initial properties.

In this work, heterogeneous pectin modification was applied to tune the wettability of the aerogels. Pectin was chemically modified at the gel state via amidation of the carboxyl groups using different amines and reaction conditions. The effect of the solvent, the reaction time, and the amine concentration on the degree of substitution were investigated. The best conditions regarding the degree of substitution and the gel morphology were chosen to fabricate grafted pectin aerogels, using six amines with different alkyl or aryl chains.

The modified pectin aerogels had density 0.1 – 0.4 g cm^{-3} and specific surface area 140 – 490 m^2 g^{-1}. The hydrophilicity was evaluated with water contact angles that were in the range of 48 – 134°, strongly dependent on the lipophilicity of the amine used for the modification. The thermal superinsulating properties of pectin aerogels were maintained after the modification for several formulations, with very low thermal conductivity (around 0.016 W m^{-1} K^{-1}).

References:

[1] S. Groult, T. Budtova, *European Polymer Journal.* **2018**, 108, 250.

[2] S. Groult, T. Budtova, *Carbohydrate Polymers.* **2018**, 196, 73.

Acknowledgements:

The work was performed in the frame of "The Transition Institute 1.5". This work was supported from the COST Action CA18125 "Advanced Engineering and Research of aeroGels for Environment and Life Sciences" (AERoGELS, https://www.cost.eu/actions/CA18125), and the Erasmus+ program, funded by the European Commission. We thank Cargil for providing pectin and the Région Sud – Provence-Alpes-Côte d'Azur for its support in the acquisition of the MAIA 3 SEM (Research Call 2019).

M11 - THE EFFECT OF CELLULASE HYDROLYSIS ON THE REFINING OF SOFTWOOD MECHANICAL PULP – FROM LABORATORY TO PILOT PLANT SCALE

Textile, Pulp, Paper & Packaging
Materials & Engineering

The effect of cellulase hydrolysis on the refining of softwood Mechanical Pulp – from laboratory to pilot plant scale

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Mechanical pulping is an energy-intensive process, with refining accounting for most of the power consumption. Enzymatic hydrolysis, particularly with cellulases such as endoglucanases, has been explored as a strategy to enhance fibre modification while reducing energy input. Cellulases selectively target amorphous cellulose, increasing fibre flexibility and reducing the refining energy needed to achieve desired fibre characteristics.

This study evaluates the interaction of enzymatic hydrolysis and refining on fibre development on the lab scale (24 g O.D. fibre) and pilot plant scale (7,700 g O.D. fibre). Softwood bleached chemi-thermomechanical pulp (BCTMP) fibres were incubated with 0.1 wt% endoglucanase in reverse-osmosis water at 3.5 wt% consistency (pH 8.9). Refining was first conducted on a laboratory scale using a PFI mill, followed by a scale-up to pilot-scale low-consistency refining with using a single disk Aikawa 150HP LC refiner with 16-inch FineBar™ plates. Fibre morphology was analyzed pre- and post-refining, and handsheets were produced to assess bulk, modulus of elasticity, and tensile index.

Refining with the PFI mill resulted in limited fibre cutting and fines generation. In contrast, low-consistency refining led to a progressive reduction in fibre length, which was more pronounced after enzymatic treatment. Fines generation from untreated fibres only increased after a minimum energy threshold was surpassed. Enzymatic hydrolysis eliminated this threshold, reducing the refining energy needed to reach a target fibre length by 40%.

For both refining methods, handsheets produced from hydrolyzed fibres exhibited reduced bulk and increased modulus of elasticity. This outcome reflects enhanced fibre cutting and greater crystallinity, as endoglucanase preferentially binds to the amorphous regions of cellulose. Treatment with 0.1 wt% endoglucanase did not significantly affect the tensile index, indicating that shorter fibres and smoother paper can be achieved without compromising mechanical strength, all while lowering energy consumption. These findings support enzymatic hydrolysis as a viable strategy for improving the energy efficiency and sustainability of mechanical pulping processes.

M12 - Tailoring Fungal Biomass for Absorbent Applications: From Composite Wound Dressings to Functional Materials

Sustainable Materials/Circular Economy
Materials & Engineering

Tailoring Fungal Biomass for Absorbent APPLICATIONS : From composite Wound Dressings to Functional Materials

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Fungal mycelium is emerging as a sustainable biomass platform for the development of bio-based materials, with tunable structural, mechanical, and biological properties enabling diverse applications [1]. In this study, we first explored the potential of *Ganoderma lucidum* [2] mycelium fractions combined with cellulose nanofibers (CNF) to fabricate porous sponges for biomedical applications. Incorporating mycelium and exopolysaccharide fractions into CNF matrices resulted in highly porous (>99%) and lightweight sponges with enhanced water absorption capacity (7000-9000%) and mechanical strength (50% increase in compressive strength). Morphological and structural characterizations confirmed that the fungal fraction also improved porosity and pore uniformity. Skin-mimicking exudate absorption tests revealed rapid uptake kinetics, reaching 400% total absorption, while hemocompatibility assessments further supported their suitability for wound dressing. Notably, the mycelium fraction exhibited the most pronounced effects, indicating that full purification of the exopolysaccharides may not be required to achieve functional sponge performance.

Beyond wound care, fungal mycelium itself, without composite formation, offers a promising route for developing absorbent materials. Current work focuses on advancing mycelium-derived materials by tuning their porosity, surface chemistry, and structural features to enhance absorption and functional performance. This contribution aims to showcase the versatility of fungal biomass valorization strategies, bridging biomedical and functional material applications through structural and compositional control.

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M13 - TEMPLATING REACTIVE MATERIALS WITH HEAT, WATER, OIL AND POLYSACCHARIDES

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Templating reactive materials with HEAT, water, oil and polysaccharides

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Catalytic reactivity is essentially determined by the accessibility of reactive sites, such as metal nanoparticles. A very common approach to increase and sustain accessibility is the immobilization of such reactive sites on precisely engineered surfaces offering a high specific surface area.

Here we show how cellulose nanocrystal-stabilized oil-in-water emulsions can serve as a template for ultra-porous, light-weight and reactive carbon-metal oxide composites. The porosity and surface area of the emulsion template is tailored by precisely adjusting the oil-to-water ratio and the ionic strength through the addition of iron(III) nitrate, which acts as a precursor for catalytically active iron oxide nanoparticles. We further examine the incorporation of the iron salt at higher concentrations (> 100 mmol/L) in the emulsions by assessing their stability and optimizing the adsorption of the precursor on the cellulose surface. The salt-enriched emulsion template is thermally converted to the catalytically active, carbonaceous material. For monitoring thermochemical transformations, we use thermogravimetric analysis coupled with mass spectrometry and infrared spectroscopy. Additionally, we use high-temperature atomic force microscopy, which gives unique information on thermal-induced morphological transformations of the system. Overall, our approach demonstrates the great potential of nanocellulose-stabilized Pickering emulsions as a universal, controllable and, yet, very simple and scalable template for designing reactive materials for catalytic applications.

M14 - SYNTHESIS OF CELLULOSE NANOFIBRIL-COATED POLYMER MONOLITH PARTICLES

Nanostructured Materials
Materials & Engineering

Synthesis of Cellulose nanofibril-coated

polymer Monolith Particles

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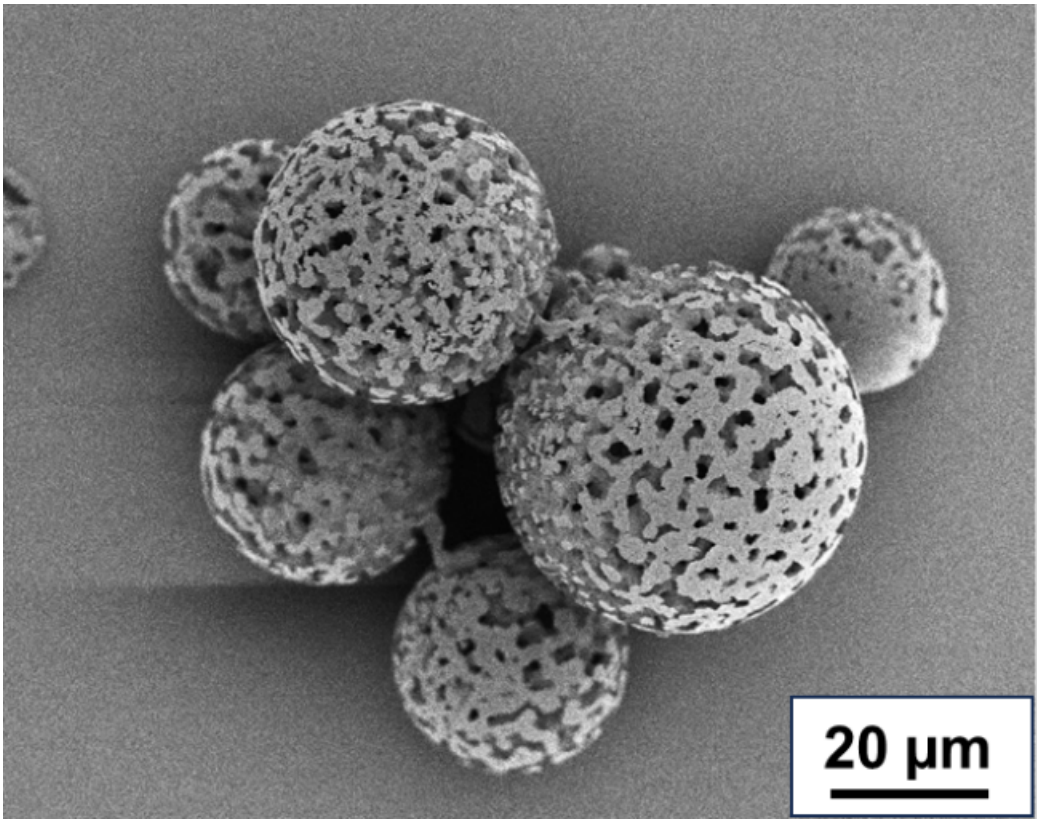
Monolith particles with a bicontinuous structure and uniform pore size distribution are promicing materials for chromatographic applications, flow reactors, and adsorbents [1]. To prepare these particles, emulsions are often used as templates for particle synthesis. Herein, we focused on cellulose nanofibrils (CNFs), which have a high specific surface area and excellent emulsifiyng performance. CNFs are also immobilized on the particle surface and are expected to exhibit unique functions such as catalytic functions, chiral recognition, and biocompatibility [2]. Herein, we aimed at a one-step preparation of core (porous structure)-shell (CNF) type polymer monolith particles by simultaneously controlling emulsion stability and polymerization-induced phase separation.

Divinylbenzene (DVB, monomer) solution containing trimethylbenzene (TMB, porogen), polydimethylsiloxane (PDMS, porogen), 2,2'-azobis 2,4-dimethylvaleronitrile, and 2-cyano-2-propyl dodecyl trithiocarbonate (chain transfer agent) was mixed with 0.1 wt% aqueous dispersion of CNFs (1:1 (v /v)). The mixture was emulsified and Ar bubbled for 5 min, then polymerized at 65℃ for 24 h. The polymerized particles were washed with tetrahydrofuran and dried at room temperature.



The obtained spherical particles had uniform bicontinuous pore structures, and the surface of particles were coated with a porous netowork of CNFs. However, non-porous thin polymer layer was formed on the particle surface presumably due to interfacial segregation of DVB monomers because the monomer have relatively high affinity for water phase compared with porogens (TMB, PDMS). Hence, to improve the affinity of the porogen-water interface, sodium dodecyl sulfate (SDS), a water soluble surfactant with long alkyl chains, was added to the polymerization system as a cosurfactant. As a result, we obtained polymer monolith particles with bicontinuous open pores (Figure 1.). The approarch using CNFs and cosurfactants is expected to be a facile tool for controlling core-shell type structures of porous polymer particles.

Figure 1. FE-SEM image of polymer monolith particles.

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[2] Tamura, Y., *et al., Sci. Rep.,* **2018**, *8*, 5021.

M15 - SULFUR BLACK IMPROVES DEPOSITION OF CONDUCTIVE POLYMER POLY(3,4-ETHYLENEDIOXYTHIOPHENE) ON CELLULOSE

Textile, Pulp, Paper & Packaging
Materials & Engineering

Sulfur black improves deposition of conductive Polymer Poly(3,4-ethylenedioxythiophene) on cellulose

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Beside other coating methods, electrically conductive polymers can be deposited on cellulose fabrics by in situ polymerisation. [1] For example, poly(3,4-ethylenedioxythiophene) (PEDOT) is deposited on a cellulose textile when the cellulose textile, the monomer 3,4-ethylenedioxythiophene (EDOT) and oxidising agent ($Na_2S_2O_8$) are successively added to water in which the oxidative polymerisation takes place.

We found that the yield of this type of deposition is significantly improved (use of 8 mg EDOT/ml water compared to 20 mg EDOT/ml water for a similar conductivity of a cellulose textile) when the fabric is dyed with sulfur black prior to the deposition of the PEDOT. Having obtained these findings, we expanded our research in two directions. Firstly, the principle of dyeing the substrate prior to the deposition of PEDOT was successfully carried out on other cellulose substrates, namely paper and mulberry paper. Secondly, the deposition of PEDOT on textiles dyed with other dyes was investigated. Some of the dyed cellulose textiles showed similar improvements in the deposition of PEDOT on them as the textiles dyed with sulfur black, while others did not.

The reasons for these results we observed in our work are not clear. Possibly surface charges or changes in the hydrophilicity of the fabric have an influence on the deposition process of PEDOT.

It is interesting that a significant improvement in the deposition of PEDOT on various cellulose substrates can be achieved with a cheap and well-known dyeing of the textiles with sulfur black.

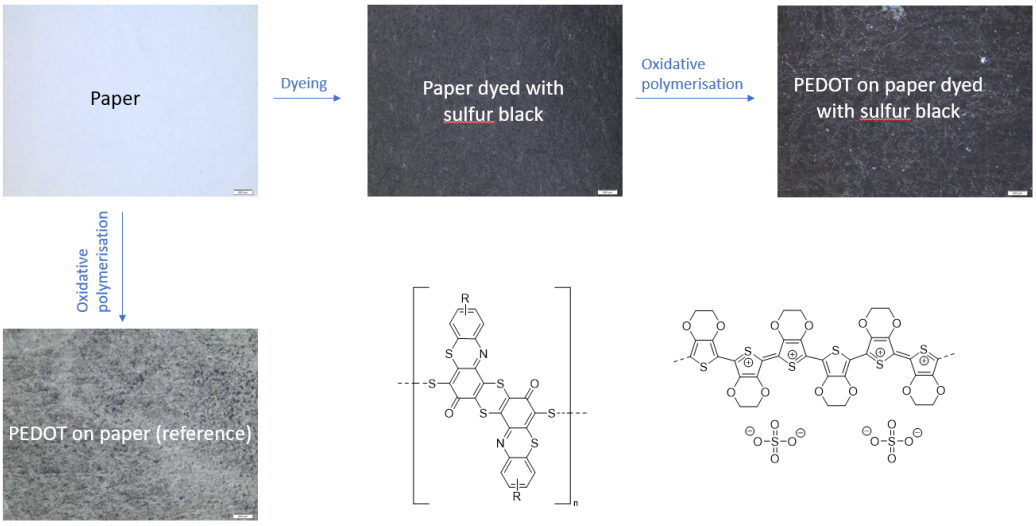

Figure 1. Images of the results of the experiments with paper as substrate, the proposed structure of sulfur black [2] and the structure of PEDOT sulfate

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M16 - Allylated Alpha-1,3-Glucan, a New Bio-Based Dispersion for Coating

Sustainable Materials/Circular Economy
Materials & Engineering

Allylated Alpha-1,3-Glucan, a New Bio-Based Dispersion for Coating

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Abstract:

Polysaccharides, a class of natural polymers, are poised to play a crucial role in the transition to a circular bioeconomy given their intrinsic sustainability attributes as well as their broad and flexible application functionality. However, native polysaccharides have certain limitations such as high hydrophilicity, lack of thermoplasticity, and inadequate mechanical properties.

A strategic partnership for high performing biomaterials (Alpha Bio) between Kemira and IFF focuses on developing a new technology platform based on enzymatic polymerization. This platform enables industrial scale synthesis of high purity and precise polymer structures such as linear alpha-1,3-glucans. The bottom-up assembly of insoluble polysaccharide polymers from soluble glucose monomers *via* enzymatic polymerization allows for the design of novel colloidal features, which can be utilized in various industrial applications.

The aim of this work was to comprehensively assess both native and carboxymethylated alpha-1,3-glucans (AG) as base polymers for synthesis of bio-based dispersions, using the development of allylation process[1]. Additionally, the produced allylated glucans have been evaluated for their potential in various applications, including surface treatment.

In the context of synthesizing allylated glucans, successful synthesis was confirmed by NMR and FTIR spectra measurements. The allylated AG, with a degree of substitution of 0.34, exhibited a homogenous dispersion with shear-thinning behavior, which is beneficial for coating applications. Moreover, the allylated AG dispersions maintained a liquid-like appearance during oscillation sweep measurement and did not gel at temperatures ranging of 25 °C to 90 °C. Self-standing films made from the allylated AG dispersion using casting method demonstrated good mechanical properties, improved hydrophobicity, and a high transmittance rate.

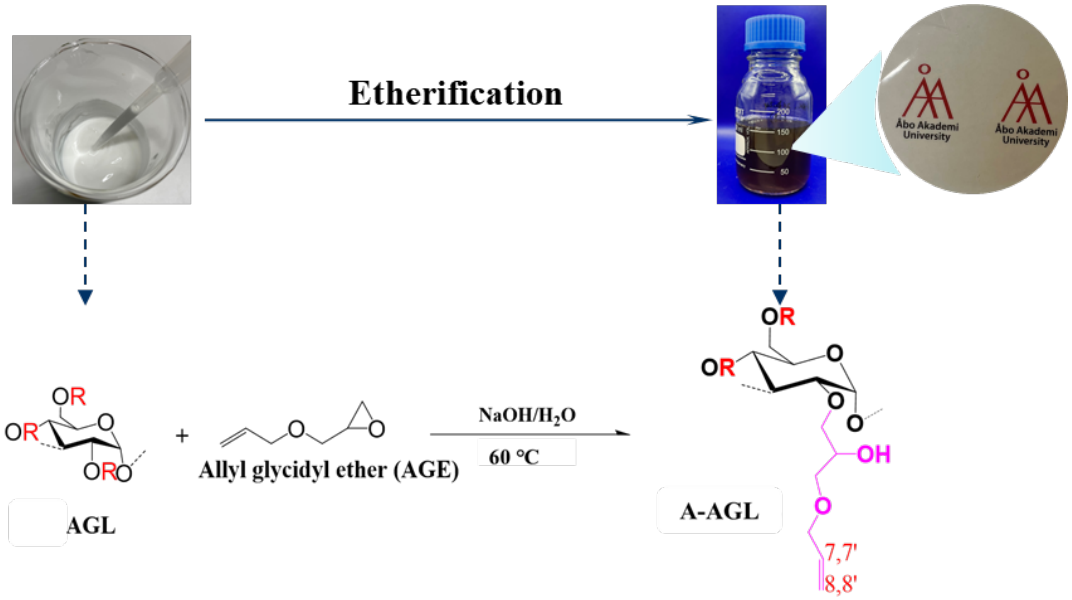

Figure 1. Schematic outline of the synthesis of allylated alpha glucan latexes: molecular structure formula, dispersions, and self-standing films.

Reference:

1. Yong, Qiwen, et al. Carbohydrate Polymers, 291 (2022): 119565.

M17 - SUBCRITICAL METHANOL-WATER ENABLES COMPLETE REMOVAL OF CHITIN-BINDING PROTEINS FROM BLACK SOLDIER FLY LARVAE

Sustainable Materials/Circular Economy
Materials & Engineering

subcritical methanol-water enables complete removal of chitin-binding proteins from black soldier fly larvae

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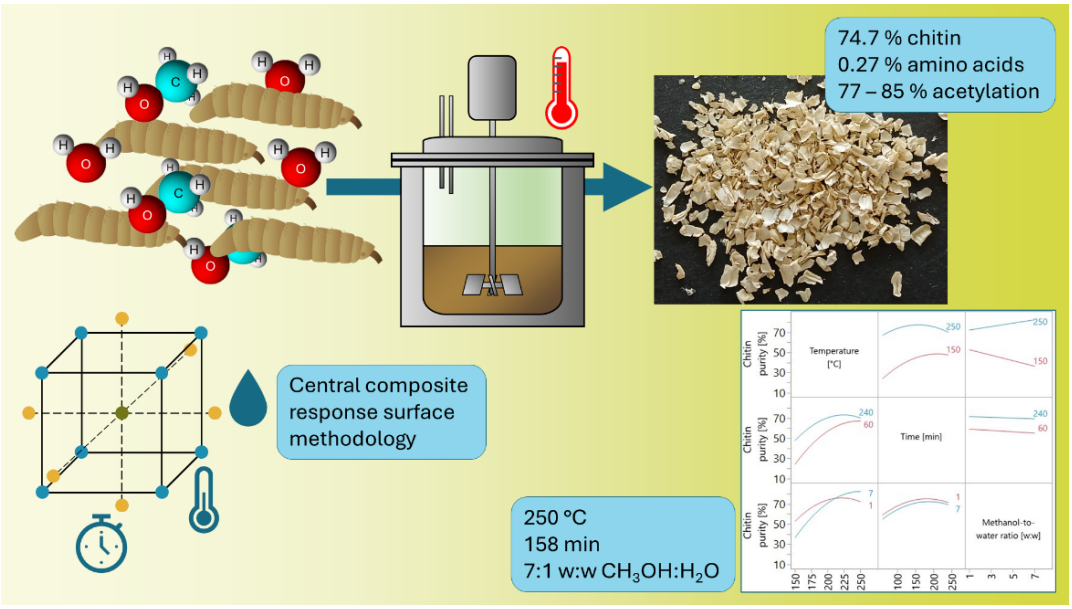

Figure 1. Overview of the novel biorefinery for the isolation of high-purity chitin

Black soldier fly (BSF, *Hermetia illucens*) larvae represent a promising resource for a circular bioeconomy, by efficiently converting organic waste into valuable biomass rich in lipids, proteins and chitin (the latter up to 5 % dry matter). Although these larvae are mainly used as animal feed, isolating compounds like chitin significantly boosts their economic value. However, the presence of chitin-binding proteins presents a major challenge in chitin isolation. Traditional chemical methods are time-consuming, generate significant chemical waste, and degrade chitin quality. To address these limitations, this study introduces a novel, sustainable biorefinery approach using a subcritical

methanol-water mixture for BSF larvae fractionation. Given the novelty of this process using a methanol-water mixture, the impact of process parameters on the purification efficiency was previously unknown. A central composite design was employed to elucidate the effects of reaction temperature (150 – 250 °C), time (60 – 240 min), and methanol-to-water ratio (1:1 – 7:1 *w*/*w*) on chitin purity and residual amino acid (AA) content. Optimal conditions were determined through response surface modelling and experimentally validated. Redundancy analysis (RDA) of individual AA further elucidated the impact of the process parameters on the residual AA profiles. As it stands, a 7:1 *w*/*w* methanol-water mixture at 250 °C for 158 min yielded a product with 75 % chitin purity and less than 0.3 % residual AA, indicating efficient removal of covalently bound proteins. The results of the RDA of individual AA suggested that Glx, the predominant remaining AA, has a correlation with chitin-binding. Lastly, this innovative process not only enables isolation of high-purity chitin but also isolation and valorisation of other larval fractions, like fatty acid methyl esters and oligopeptides. In conclusion, the developed process provides a more sustainable, efficient pathway to obtain high-quality chitin from BSF larvae, suitable for diverse industrial and medical applications, while contributing to a circular bioeconomy.

M18 - Strength enhancement of LMFC-reinforced packaging paper using chitosan-modified white-water

Textile, Pulp, Paper & Packaging
Materials & Engineering

Strength Enhancement of LMFC-Reinforced Packaging Paper Using Chitosan-Modified White-Water

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Lignin-containing microfibrillated cellulose (LMFC) has demonstrated significant potential in enhancing paper strength, but its application under industrial conditions remains limited. This study evaluates the effect of mechanically produced LMFC on paper properties in the presence of industrial white-water. Additionally, it investigates the role of chitosan in optimizing white-water characteristics to enhance the LMFC retention in the packaging grade paper.

A specific concentration of LMFC was added to unbleached pulp, leading to improvements in key mechanical properties, including tensile index, elongation at break, tear index and internal bonding strength (IBS). However, LMFC retention was lower in white-water compared to demineralized water. To address this, chitosan was added in varying concentrations in the white-water, which enhanced the retention of LMFC and fines. This resulted in denser paper sheets with improved fiber bonding, reduced air permeability, and lower water absorption. At the optimal chitosan concentration, all strength properties increased by more than double, with significant improvement in IBS.

Moreover, chitosan reduced the cationic demand of white-water while maintaining stable conductivity and pH, thereby improving process stability. It also facilitated in the retention of anionic colored compounds, enhancing the economic efficiency of industrial packaging paper production. These findings highlight the synergistic role of LMFC and chitosan-treated white-water in enhancing paper strength and resource efficiency, making it a viable approach for high-performance packaging applications.

Acknowledgement

This work was carried out in the framework of the project agenda "From Fossil to Forest - FF2F", funded by the PRR - Recovery and Resilience Program, of the Portuguese Republic, and by the Next

Generation European funds (Call N.º 02/C05-i01/2022, Component 5 – Capitalization and Business Innovation - Mobilizing Agendas for Business Innovation). Authors would like also to thank the CERES - Chemical Engineering and Renewable Resources for Sustainability Research Center, funded by Fundação para a Ciência e a Tecnologia (FCT), through the base (DOI:10.54499/UIDB/00102/2020) and programmatic (DOI: 10.54499/UIDP/00102/2020) budgets.

M19 - STARCH-g-GLYCIDYL METHACRYLATE/N,N'-DIMETHYLACRYLAMIDE-BASED HYDROGEL REINFORCED WITH ACTIVATED CARBON

Sustainable Materials/Circular Economy
Materials & Engineering

starch-*g*-glycidyl methacrylate/n,n'-dimethylacrylamide-based hydrogel reinforced with Activated carbon

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Hydrogels are three-dimensionally structured polymeric matrices capable of entraping molecules within their structure, and releasing them after absorbing water. Even though these matrices might be efficient in absorbing and releasing molecules, their mechanical performance may require improvements. Activated carbons (ACs) might be suitable candidates for this matter. They usually display high surface areas, allowing them to adsorbe high amounts of molecules onto their surface, and dessorb them under proper conditions [1]. The combination of hydrogels and ACs should, therefore, have a posite effect on the release and mechanical performance of the matrix.

This work evaluated the suitability of adding ACs, modified with glycidyl methacrylate (GMA; ^{GMA}AC), to a 25:75 % w/w starch (St)-*g*-GMA (^{GMA}St)/N,N'-dimethylacrylamide (DMAAm)-based hydrogel as a mechanical reinforcement, and additional fertilizer releasing system. The matrices were also subjected to a hydrolysis step after the synthesis to introduce ionic groups into the polymeric structure.

Mechanical tests suggested that the hydrolysis increased the viscoelastic characteristic of the matrices due to the removal of physically bonded chains. But the results also indicated that ^{GMA}AC contributed more effectively as an effective mechanical enhancer to the samples. The swelling degree of the matrices strongly depended on the ionic strength of the medium, reaching (438.2 ± 41.60) g g^{-1} at an ionic strength of $1x10^{-5}$ M and T = 25 °C for sample containing 0.5% w/w of ^{GMA}AC. The high content of negatively charged groups in this matrix probably increased the repulsion between adjacent groups, ultimately leading to this high swelling degree compared to the other matrices. The matrices were also responsive to pH and temperature variations. However, the ranges used in this work mostly led to statistical equivalencies.

Table 1. The swelling degree* and Young's modulus of the hydrolyzed $^{GMA}St_{25}DMAAm_{75}/^{GMA}AC$ hydrogels.

Sample	Swelling degree (g g^{-1})	Young's modulus (MPa)

$^{GMA}St_{25}DMAAm_{75}/^{GMA}AC_0$	48.3 ± 1.3	$7.0x10^{-4} \pm 1.0x10^{-4}$
$^{GMA}St_{25}DMAAm_{75}/^{GMA}AC_{0.5}$	438.2 ± 41.60	$2.4x10^{-3} \pm 2.0x10^{-3}$

*at an ionic strength of $1x10^{-5}$ M, T = 25 °C.

The hydrogel matrices produced in this work might be appealing for agricultural purposes because they would be able to release urea in the soil. This release would depend on the pH, ionic strength, and temperature. The matrix containing ^{GMA}AC also showed bigger stability against consecutive swelling and drying cycles, preserving their integrity and performance for over 15 cycles, suggesting that they would have extended efficiency. Despite the potential of these matrices, in vivo assays are still required to determine if they would be truly effective and beneficial to the soil.

[1] P. Vejan, T. Khadiran, R. Abdullah, N. Ahmad, *J. Control. Release*, **2021**, 339 321–334.

M20 - Recycling brewers' spent grains in an urban environment: towards a decision-making tool for sustainable solutions

Sustainable Materials/Circular Economy
Materials & Engineering

Recycling brewers' spent grains in an urban environment: towards a decision-making tool for sustainable solutions

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This project aims to make cities more resilient and sustainable by managing bio-waste differently. The aim is to reorganize material flows and develop circular management of local bio-resources with a territorial approach, by reintroducing bio-waste into a virtuous cycle of bio-sourced materials. To start with a concrete case study, the chosen model focused on brewers' spent grain (BSG) produced by urban and suburban brewers. By exploring new non-food applications, the ambition here is to develop a working method that identifies all the players in the sector (waste producers, waste processors, new product developers and manufacturers, territorial policy makers, consumers) and enables the effective co-construction of a circular economy.

This exploratory work brings together economists and material engineers. It proposes the construction of a decision-making tool integrating environmental, social and technical dimensions, in line with the definition of the circular bioeconomy. The development of non-food, non-energy use of waste is actually revealed as relevant but undervalued. Thermocompression-treated materials are produced without the use of resins or binders. The thermopressing conditions and length of the fibers in all the materials tested were identified as decisive parameters for mechanical properties.

This work investigates the location, nature and quantity of waste, possible transformations, but also the demands and constraints of waste producers. The idea to mobilize the entire industry to find local, innovative, relevant and unifying solutions.

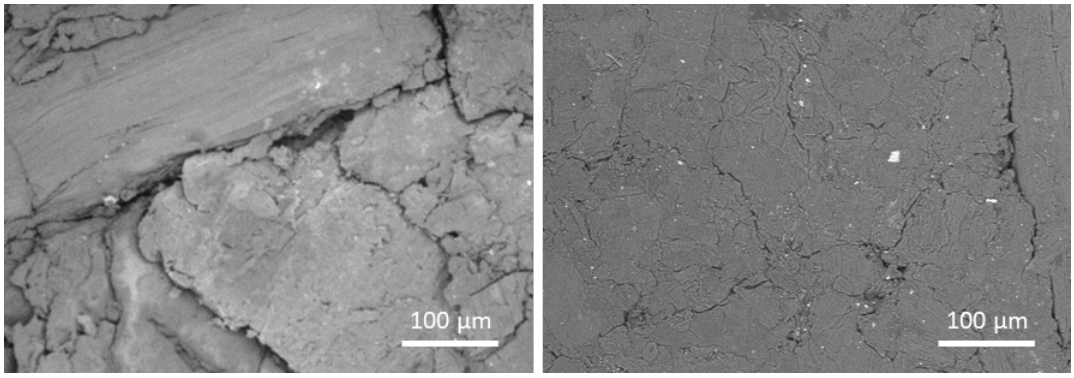

Figure 1. SEM visualization of the surface of thermocompressed samples using non-optimal (left) and optimal (right) process conditions

M21 - Recovery of cellulose nanocrystals produced via hydrochloric acid hydrolysis

Sustainable Materials/Circular Economy
Materials & Engineering

Recovery of cellulose nanocrystals produced via hydrochloric acid hydrolysis

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In our current day, increasing efforts are being made to reduce society's dependence on fossil resources and to transition to a bio-based circular economy. For this reason, there is a focus on creating new sustainable materials from biological and renewable resources. Cellulose is an attractive and bio-renewable feedstock due to its availability and low cost. One material that can be synthetised with cellulose are cellulose nanocrystals (CNCs).

The mechanism to synthesize CNCs is through its hydrolysis with an acid, which usually is sulfuric acid (H_2SO_4). However, this process results in the partial surface-functionalization of the CNCs with sulphate half-ester groups, which may not be desirable for certain applications. In contrast, hydrolysing cellulose with hydrochloric acid (HCl) avoids this surface modification, leaving the CNCs' hydroxyl groups untouched while they remain available for the surface-functionalization of the CNCs at later stages, which is of significant interest.

Currently, the methods used for the separation and purification of CNCs produced with HCl are centrifugation and dialysis, which are highly energy-intensive and time-consuming, respectively. For that reason, this research explores and evaluates alternative methods – that utilize of the properties of our reagents in the CNC-HCl solution post-reaction – with the aim of improving the overall efficiency of the production process.

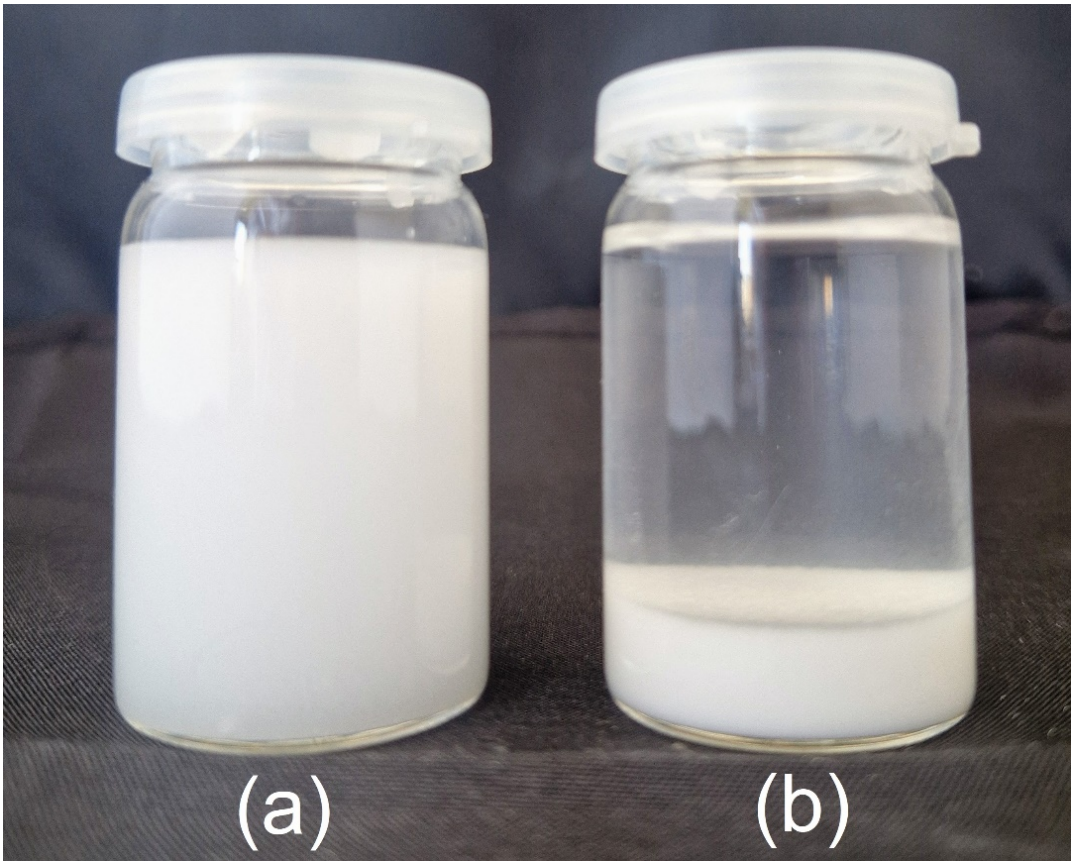

Fig. 1. CNCs at 5 wt.% in water: (a) Immediately after mixing, (b) One hour after mixing.

M22 - PRODUCTION OF HOLOCELLULOSE FIBRES FROM OAT HUSK

Sustainable Materials/Circular Economy
Materials & Engineering

Production of holocellulose fibres from oat husk

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Annually 2 billion tons of agricultural side streams and waste are produced worldwide, which are mainly underutilised either burned or left at the fields. Oat husk is the outer shell that surrounds the oat grain and represents about 27% of oat grain weight. Oat husk constitutes a major by-product of oat processing during dehulling, with approximately 6.79 million tons being produced globally and 2.04 million tons only in Europe. These agricultural side streams are rich lignocellulosic fibres, which are attractive materials that can replace traditional fossil-based alternatives due to their superior mechanical, thermal, and chemical properties [1]. Lignocellulosic fibres are biological materials rich in cellulose, hemicellulose and lignin precisely organized from the nano to the macroscale to fulfill their biological functions, providing stability and strength against mechanical and osmotic stress to plant cells. The production of lignocellulosic fibers typically involves harsh chemical processes, which results in a combined loss of carbohydrates, hemicellulose in particular, that could be used for diverse applications [2]. Hemicelluloses can enhance the bonding between cellulose fibrils, improving the mechanical properties of cellulose fibrillar networks [3]. In this context, holocellulose fibres retaining most of the hemicellulose around the cellulose fibrillar structure, emerge as a high-quality sustainable building block for the preparation of lignocellulosic materials. The aim of this work is to optimise a mild delignification process using peracetic acid (PAA) to produce holocellulose fibres from oat husk, retaining as much hemicellulose as possible. Amongst the different delignification methods, peracetic acid (PAA) has shown high selectivity towards lignin removal while preserving the native composition of the lignocellulosic fibres [4,5]. We have optimized the temperature and pH conditions during the delignification treatment, and we have compared the compositional and structural properties of the derived holocellulose materials, including hemicellulose content, delignification efficiency, and fiber morphology.

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M23 - PROGRAMMABLE ASSEMBLY OF CELLULOSE NANOCOMPOSITES AT INTERFACES

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

programmable Assembly of cellulose nanocomposites at interfaces

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Cellulose nanocrystals (CNCs), as charged rod-like nanoparticles, have gained attention as eco-friendly stabilizers for Pickering emulsions, yet their inherent hydrophilicity necessitates surface modification for optimal interfacial performance [1]. This study presents an innovative approach to fabricate programmable cellulose nanocomposites through biomimetic integration with phase-transitioned bovine serum albumin (PTB). By inducing disulfide bond reduction-triggered amyloid-like aggregation of BSA, we achieve instantaneous self-assembly of PTB oligomers onto CNC surfaces, creating PTB/CNC nanocomposites that synergistically combine enhanced interfacial activity with bioadhesive properties derived from protein structural reorganization. The resultant hybrid system demonstrates superior interfacial stabilization capabilities, enabling spontaneous adsorption at fluid interfaces for effective nanoemulsion and foam stabilization. Precise control over interfacial behavior is achieved through adjustable PTB-to-CNC ratios, allowing tailored performance optimization (Figure 1). These nanocomposite-stabilized nanoemulsions show significant potential in sustainable agricultural applications including precision pesticide delivery and smart fertilization systems, while also exhibiting broad applicability across diverse sectors such as functional coatings, cosmetic formulations, and targeted drug delivery platforms that demand controlled droplet deposition and surface adhesion.

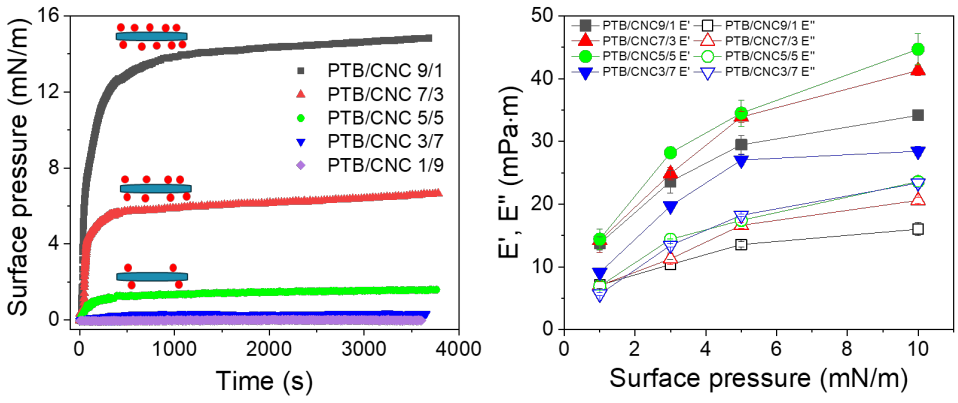

Figure 1. Behaviour of the PTB/CNC nanocomposites at air-water interface

[1] Pascal B.; Peter F., *ADV COLLOID INTERFAC* **2020**, *276*, 102089.

M24 - CHALLENGES OF NEW PULP VALUE CHAINS FOR THE DETERMINATION OF MOLECULAR WEIGHT DISTRIBUTION BY SEC

Textile, Pulp, Paper & Packaging
Materials & Engineering

Challenges of new pulp value chains for the determination of molecular weight distribution by SEC

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The demand for fibers and the annual production capacity of man-made cellulose fibers (MMCF) have been increasing for several years. The most important, MMCFs are viscose, modal and lyocell fibers. Today, these types of MMCF are mostly produced using well-adjusted, high-purity chemical wood-based pulps. The increased demand for fibers and the large quantities of pulp required cannot be met by current sources alone in the future. It is therefore of considerable interest to use alternative pulps, such as those made from hemp and linseed flax from agricultural residues, dissolving softwood and hardwood pulps, untreated and enzymatically treated paper pulps or recycled cotton waste from the textile sector. An important process-critical parameter for adapting the pulps to the processes is the molecular weight and the molecular weight distribution (MWD).[1] The method typically used for this is size exclusion chromatography (SEC), in which the pulps are first molecularly dispersed in dimethylacetamide/LiCl and analyzed using molecular weight-sensitive detectors. In particular, pulps with a hemicellulose content, high crystalline pulps and pulps with a high molecular weigth content pose a particular challenge for this measurement method. The presentation will address and discuss the various problems and present own approaches developed to solve them.

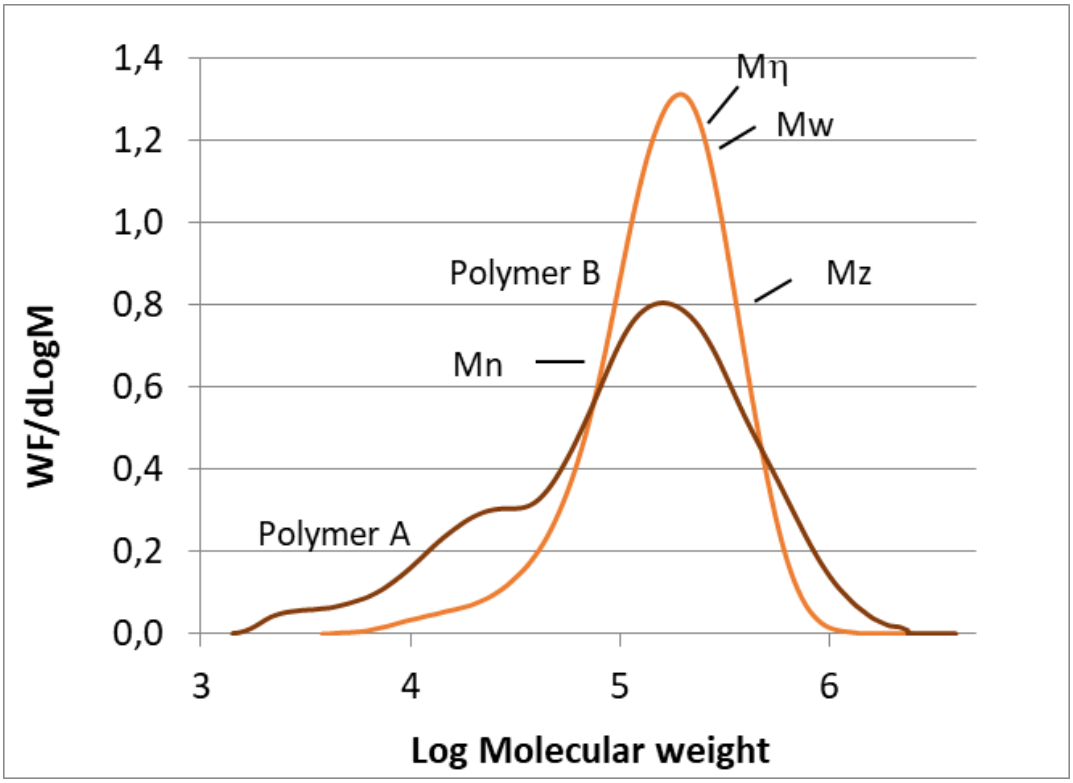

Figure 1. Typical Molecular weight distribution (MWD) of two different polymers a and b and mean values of their MWD

[1] Kosan, B. ; Thümmler, K ;·Meister, F. ; ·Römhild, K., Cellulose **2024,** *31*, 1941–1955

[

M25 - OXALIC ACID-FUNCTIONALIZED CELLULOSE NANOFIBERS FOR ENHANCED CO_2 CAPTURE IN ELECTROSPUN MEMBRANES

Environmental Remediation
Materials & Engineering

Oxalic Acid-Functionalized Cellulose Nanofibers for Enhanced CO_2 Capture in Electrospun Membranes

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This study presents a novel approach to enhance CO_2 capture using electrospun membranes with cellulose acetate (CA) as the matrix polymer, polyethyleneimine (PEI) as the adsorptive polymer, and anionic cellulose nanofibers (CNF) as immobilization and strenghtening agents. While PEI's accessible amino groups played the role of adsorption sites for CO_2, CNFs with carboxyl groups were necessary to ensure the retention of this polymer within the membrane by means of ammonium carboxylate formation [1]. In turn, they had good compatibility with the CA matrix.

Different strategies for modifying cellulose were explored, with oxalic acid-treated CNF proving to be the most effective. While TEMPO-oxidized CNF (3 mmol NaClO/g) were unsuitable for electrospinning due to excessive viscosity, among other issues, the oxalic acid treatment produced CNF that was more compatible with electrospinning. The optimal formulation, consisting of 75 wt% oxalic acid-treated CNFs and 4 wt% PEI, maximized CO_2 adsorption capacity without compromising the structural integrity of the membranes, as seen in Figure 1.

CA/PEI/CNF membranes achieved CO_2 adsorption capacities over 4 mmol/g, following pseudo-first-order kinetics and maintaining stable performance over five adsorption-desorption cycles.

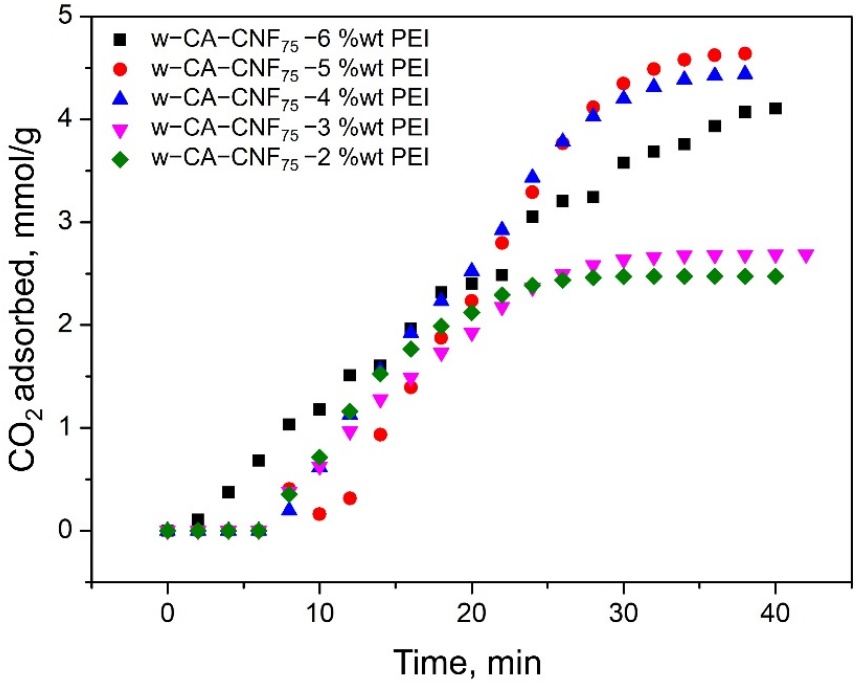

Figure 1. CO_2 adsorption rate for membranes containing 6 wt% CNF_{75} with different PEI contents of 2, 3, 4, 5, and 6 wt%, at 25 °C [1].

[1] Bastida, G. A.; Aguado, R. J.; Delgado-Aguilar, M.; Tarrés, Q. *Journal of Cleaner Production* **2025**, *486*, 144428.

M26 - Nanocellulose-based aerogels for water remediation through textile waste upcycling

Environmental Remediation
Materials & Engineering

Nanocellulose-Based Aerogels for Water Remediation through Textile Waste Upcycling

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The extraction of high added-value nanomaterials from textile waste offers a promising approach for resource valorisation. At the same time, the textile industry poses a considerable environmental threat by discharging harmful dyes and heavy metals into water, resulting in damage to biodiversity and the need for expensive wastewater treatment processes [1].

In this work nanocellulose-based aerogels derived from recycled cotton, viscose fibres and cellulose extracted from polyethylene terephthalate (PET)/cellulose fabric [2] were developed. These aerogels were evaluated for their efficiency in removing metals and dyes from contaminated water, thereby promoting a circular and environmentally sustainable approach to water purification.

Various chemical pre-treatments were explored to enhance the extraction of cellulose nanofibers (CNF) from textile waste [1,3]. Subsequently, the pre-treated fibres were TEMPO-oxidized and subjected to mechanical treatment to achieve nanoscale dimensions [4]. The resulting CNF served as building blocks for the development of aerogels and were combined with a cross-linker and a co-crosslinker, obtaining a stable formulation [5]. Finally, nanocellulose-based aerogels were obtained through freeze-drying and thermal treatment. These nanomaterials were characterized and their contaminants removal capabilities were evaluated. Outstanding sorption performances were exhibited with efficient removal of heavy metals (Cu^{2+}, Fe^{3+}, Pb^{2+}, Ni^{2+}) and organic dyes bearing sulfonate groups from test solutions.

In conclusion, the upcycling of textile waste into highly efficient nanomaterials for wastewater treatment established a circular approach for water purification. This process not only addressed environmental concerns but also contributed to the sustainable reuse of textile waste, providing an innovative solution for environmental purposes.

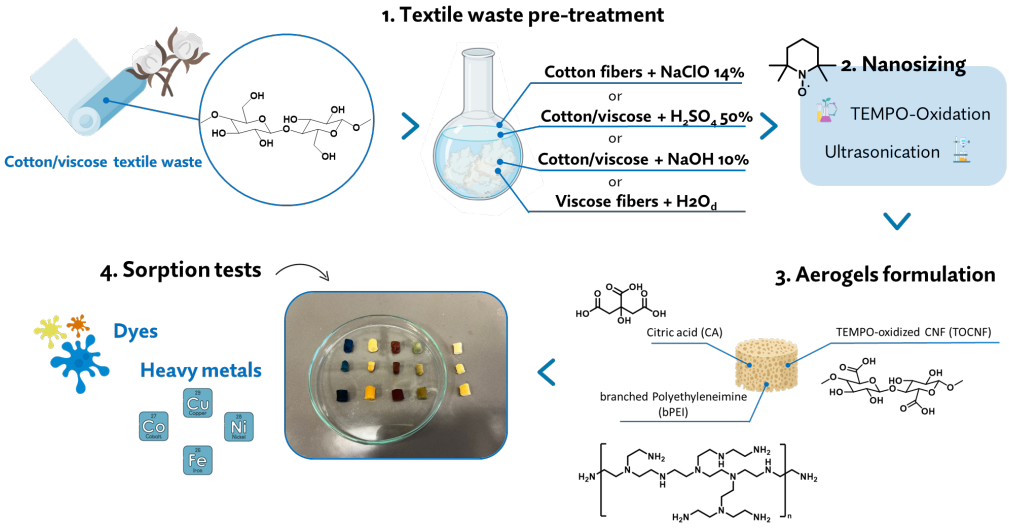

Figure 1. Schematic representation of aerogels production and application.

[1] Sathasivam, T., Sugiarto, S. PekYin Yew, M. *et al., Nanoscale* **2024**, *16*, 14168

[2] Truscello, A., Sartiano, C., Galimberti, M. S. *et al., Journal of Applied Polymer Science,* **2025,** 142(10)

[3] Matsuki, S., Kayano, H., Takada, J. *et al., CS Sustainable Chem. Eng.* **2020**, *8*,17800

[4] A. Isogai, T. Saito, H. Fukuzumi, *Nanoscale*, **2011**, *3*, 71

[5] Riva L., Pastori N., Panozzo A., *Nanomaterials* **2020***, 10*, 157

M27 - MODULATING REDUCTIVE AMINATION FOR MPEG END-GRAFTING ON CELLULOSE NANOCRYSTALS: ASSESSING DISPERSIBILITY, BIODEGRADABILITY, AND CHIRALITY

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Modulating Reductive Amination for mPEG End-Grafting on Cellulose Nanocrystals: Assessing Dispersibility, Biodegradability, and Chirality

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Cellulose nanocrystals (CNCs), derived from renewable sources, are highly crystalline and possess exceptional mechanical strength. However, their strong hydrogen bonding leads to aggregation [1], limiting their potential applications, particularly in biomedicine. Similar to other polysaccharides like alginate and chitosan, grafting methoxy polyethylene glycol (mPEG) onto CNCs significantly improves their dispersibility, biocompatibility, and applicability in advanced fields such as biomedicine and nanocomposites [2]. End-grafting mPEG onto CNCs not only enhances biocompatibility but also introduces steric hindrance, reducing intermolecular interactions and improving dispersion in aqueous and polymer matrices. Additionally, the presence of both a polyethylene glycol (PEG) moiety and an amine group in methoxypolyethylene glycol amine facilitates surface modification at the reducing end groups, making it a versatile reagent for nanomaterial functionalization and conjugation with nanometals. This modification imparts enhanced hydrophilicity, tunable thermoresponsive properties, and improved mechanical stability, thereby promoting the formation of stable colloidal suspensions and modulating chirality [3], [4].

In this study, we successfully synthesized end-grafted CNCs with mPEG via reductive amination, evaluated reaction conditions such as reaction time and mPEG concentration by t-test. The efficiency of end-grafting was confirmed through heteronuclear single quantum coherence nuclear magnetic resonance (HSQC-NMR) and quantified using the bicinchoninic acid (BCA) assay. Furthermore, the physicochemical properties of mPEG-modified CNCs (mPEG-CNCs) were systematically characterized. Zeta potential and size distribution analyses were employed to assess surface charge and dispersion behavior, while atomic force microscopy (AFM) provided insights into morphological modifications. Given that end-grafting influences CNC chirality, we investigated its impact on the lower critical solution temperature (LCST) of mPEG and phase transition behavior, alongside pitch measurement to evaluate chiral structure alterations.

Our findings demonstrate that end-grafting mPEG onto CNCs significantly improves their colloidal stability, surface properties, and chiral characteristics, thereby expanding their potential applications in biomedical formulations, nanocomposite systems, and responsive materials. This study provides a foundational approach for the rational design of functionalized CNCs with enhanced physicochemical properties tailored for advanced material applications.

[1] A. Abbasi Moud, ACS Omega, 7, 35, 30673–30699, 2022.

[2] F. Sun, H. R. Nordli, B. Pukstad, E. Kristofer Gamstedt, and G. Chinga-Carrasco, J Mech Behav Biomed Mater, vol. 69, pp. 377–384, 2017.

[3] Y. Qi, S. Wang, J. Sun, J. Song, H. Li, and J. Guo, Int J Biol Macromol, vol. 260, p. 129544, 2024.

[4] Y. Zhang, Y. Peng, Y. Tian, H. Xu, X. Yin, and X. Hou, Colloids Surf A Physicochem Eng Asp, vol. 695, p. 134284. 2024

M28 - LIGNIN BASED CARBON AEROGELS FOR GAS FILTER APPLICATIONS

Sustainable Materials/Circular Economy
Materials & Engineering

Lignin based carbon aerogels for gas filter applications

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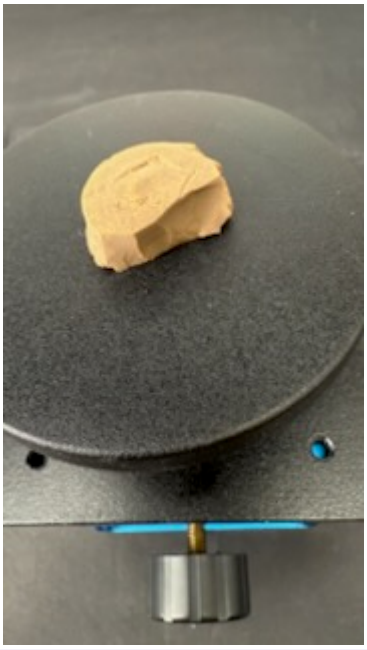
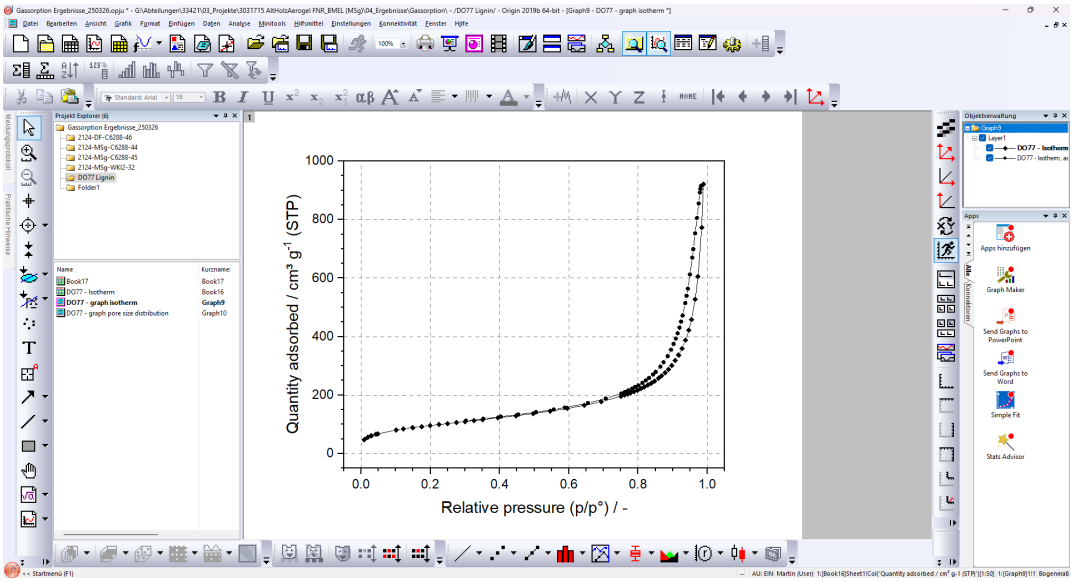
Cellulose and lignin are among the most widespread biopolymers in the world and are found in varying proportions in all plant cells. One resource which is especially interesting is wood which is available in large quantities in Germany and Europe and which is used extensively in our daily lives. Even more, waste wood, which has reached the end of its life cycle and is produced in large quantities every year, is becoming an interesting source of raw materials for the synthesis of new high-quality and sustainable products.

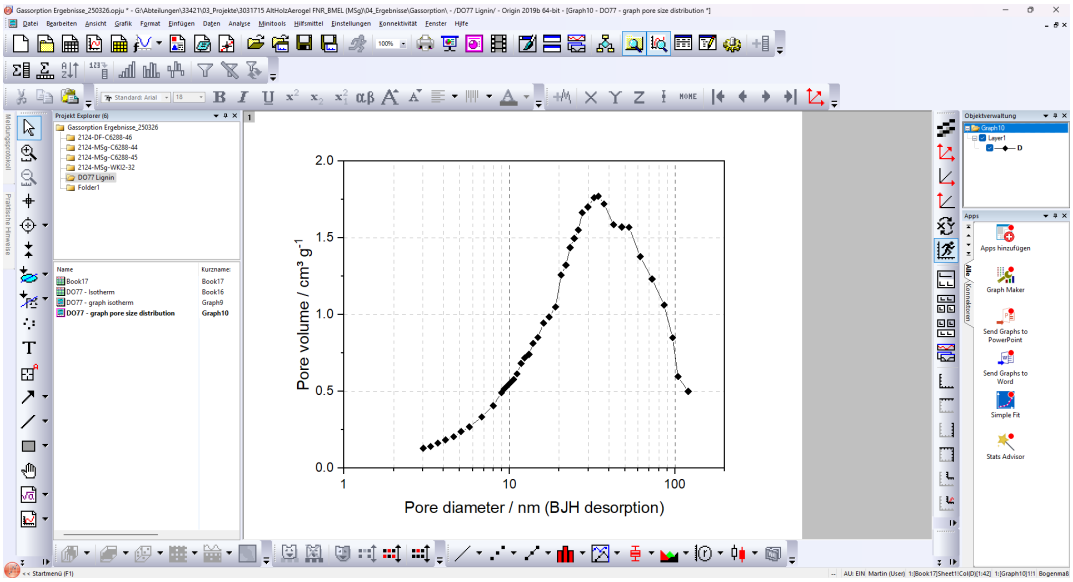
One group of such highly functional materials are aerogels, highly porous solids with up to 99 % pore volume, large inner surfaces of up to 3000 m^2/g and small pore sizes. These properties result in low thermal conductivities and high porosities and offer an interesting range of applications such as thermal insulation and filtering applications.

In the presented project lignin-based aerogels are tested for gas filter applications. For this purpose, lignin aerogels are synthesized according to the method described by Aufischer et al. [1]. These aerogels are then carbonised into carbon aerogels and activated with carbon dioxide to form aerogels with an increased inner surface area, a high volume of micropores and the ability to adsorb a wide variety of pollutants.

The synthesis of the aerogels with the reaction of different lignin-formaldehyde ratios as well as the following steps solvent exchange, supercritical drying with CO_2, carbonisation and activation with CO_2 are described. For the different lignin to formaldehyde ratios the inner surface areas, the total pore volume and the micropore volume as well as the pore size distribution will be presented. For selected compositions the microstructure and the characteristic data before and after the carbonisation and activation will be shown.




Quantity adsorbed / cm³ g⁻¹ (STP)
Relative pressure (p/p°) / -


Pore volume / cm³ g⁻¹
Pore diameter / nm (BJH desorption)

BET surface area: 350 m^2 g^{-1}

Figure 1. Lignin aerogel with its N_2-isotherm and pore size distribution

This work was performed within the project AltHolzAerogel (funding number 2221HV038B) supported by the Federal Ministry of Food and Agriculture.

[1] Aufischer, G.; Kamm, B.; Paulik, C., International Journal of Biobased Plastics, **2025**, Vol. 3, 1, 19-28.

M29 - ION-CONDUCTIVE PAPERS – INFLUENCE OF FIBER PROCESSING

Sustainable Materials/Circular Economy
Materials & Engineering

Ion-conductive papers – influence of fiber processing

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A recent application for paper-based composites is their use as ion-selective membrane in fuel cells and redox flow batteries [1]. In contrast to the perfluorinated ion exchange membranes currently in widespread use, cellulose-based membranes do not contain any harmful halogens and are therefore more environmentally friendly and more easily biodegradable.

However, these ionically conductive modified papers still exhibit the disadvantages of lower ion selectivity and ionic conductivity and, above all, cross-diffusion.

Here we investigate the influence on these parameters on varying the properties of the fiber content of this composite material. To compete with current market leaders, bio-based membranes must first show a comparable level of cross-diffusion between the two electrolytes of the flow battery system. For numerical comparison, a (cross) diffusion test with an electrolyte-like substance provides information. Initial diffusion tests with unrefined, long-fiber 80 g/m² laboratory sheets show that pulp refinement reduces cross-diffusion by 26%. Increasing the basis weight by 20 g/m² at the same degree of refining leads to a reduction in diffusion by a factor of 2.

We evaluated the influence of basic papermaking parameters such as fiber type, refining energy, basis weight, hydrophobicity, and wet strength on membrane performance. We tested cross-diffusion, electrochemical impedance, battery lifetime, and battery performance. The results help understand how fiber processing and fiber network affects the ion transport and electrochemical properties of the final membrane composite material.

[1] Lander, S., Vagin, M., Gueskine, V., Erlandsson, J., Boissard, Y., Korhonen, L., Berggren, M., Wågberg, L. and Crispin, X. (2022), Sulfonated Cellulose Membranes Improve the Stability of Aqueous Organic Redox Flow Batteries. Adv. Energy Sustainability Res., 3 : 2200016. https://doi.org/10.1002/aesr.202200016

M30 - Investigation of Chitin-Protein Composite Materials Obtained from Insects

Sustainable Materials/Circular Economy
Materials & Engineering

Investigation of Chitin-Protein Composite Materials Obtained from Insects

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[3]Department of Chemical & Petroleum Engineering, Khalifa University of Science & Technology, Abu Dhabi, United Arab Emirates.

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Black soldier fly (BSF) farming offers a promising way to transform organic waste into valuable resources. These insect larvae efficiently convert waste into high-quality proteins, fatty acids, and chitin that have applications in animal feed, agriculture, and various industries. Among these products, chitin has attracted considerable attention as a versatile and sustainable resource for materials applications. However, chitin extraction has significant challenges due to the intrinsically strong interactions between chitin and proteins. This work investigates various sustainable chemical treatments to selectively remove proteins yielding chitin/protein composites with tunable properties. Infrared spectroscopy, nuclear magnetic resonance spectroscopy, and elemental analyses, were utilized to characterize the chemical composition of the resulting composites. Additionally, we examined how varying levels of residual protein affect the performance of chitin-based materials, including nanopapers and composites prepared with epoxidized plant oils. Mechanical testing was conducted to evaluate the strength and flexibility of these materials. This research supports the development of sustainable, insect-derived biomaterials and contributes to advancing a circular bioeconomy. This research advances the sustainable production of insect-derived materials, contributing toward a circular bioeconomy.

M31 - IMPACT OF MOLECULAR WEIGHT REDUCTION ON THE ANTIBACTERIAL EFFICACY OF CHITOSAN

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Impact of Molecular Weight Reduction on the Antibacterial Efficacy of Chitosan

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Abstract

Chitosan, a natural biopolymer derived from chitin, is renowned for its broad-spectrum antimicrobial activity against a wide range of bacteria and fungi, as well as excellent biocompatibility [1]. Antimicrobial efficacy of chitosan is strongly influenced by molecular weight (MW), which affects solubility and the ability to interact with microbial cell surfaces and membranes [2]. In this study, chitosan was subjected to controlled acid hydrolysis using 0.6 M hydrochloric acid at 70 °C to produce fractions with varying MWs. Samples were collected at specific time intervals, precipitated in ethanol, and vacuum-dried. The molecular weights of the degraded samples were determined via gel permeation chromatography (GPC), and their antimicrobial efficacy was assessed against a range of gram-positive and gram-negative bacteria using Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) assays.

Results revealed a clear inverse relationship between acid treatment duration and chitosan MW, with prolonged treatment leading to significantly lower MWs. Interestingly, despite decreasing MW, the antibacterial activity remained largely unchanged across a wide range from 1273 to 7 kDa showing that low-to-moderate MW chitosan retains comparable antimicrobial effects to its high-MW counterpart. Since high-MW chitosan is often challenging to work with due to limited solubility and high viscosity, these findings suggest that lower-MW chitosan offers a more practical alternative while maintaining equivalent antibacterial performance. However, when the MW dropped to 2 kDa, a sharp decline in antibacterial activity was observed across all tested strains (Table 1). This highlights a critical molecular weight threshold below which chitosan's efficacy is significantly reduced, emphasizing the importance of MW optimization for its use in antimicrobial applications.

MW (kDa)	*E. Coli* (μg/mL)	*Staphylococcus aureus* (μg/mL)	*Pseudomonas aeruginosa* (μg/mL)
1273	256	128	256
445	256	256	256
200	128	128	128
49	128	256	128
45	128	256	256
14	128	256	128
7	128	256	256
2	>1024	>1025	>1026

Table 1. MIC values (μg/mL) for chitosan with different molecular weights tested on various bacteria in Mueller Hinton Broth at pH 5.8.

[1] Másson, M. Antimicrobial properties of chitosan and its derivatives. In: Chitosan for Biomaterials III: Structure–Property Relationships; Springer: Cham, 2021; pp. 131–168.

[2] Kong, M.; Chen, X.G.; Xing, K.; Park, H.J. Int. J. Food Microbiol. 2010, 144, 51–63.

M32 - Impact of lignin incorporated TEMPO-oxidized cellulose nanofibril separators on supercapacitor performance

Energy Applications
Materials & Engineering

Impact of lignin incorporated TEMPO-oxidized cellulose nanofibril separators on supercapacitor performance

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The demand for safe, efficient, and eco-friendly energy storage is rising rapidly, making innovation critical in each device component, including separators. [1] The aim of this study is to investigate lignin-containing TEMPO-oxidized cellulose nanofibril networks (LCNNs) as a class of high-performance, flexible, and sustainable separator for supercapacitors with a focus on amount of lignin. Using wood particle derived TEMPO-oxidized cellulose nanofibrils (TO-CNFs) and Kraft lignin (KL), a commercially available, redox-active product of the pulping industry, we aim to systematically explore how KL content modulates the structural, mechanical, and electrochemical behavior of the thin LCNNs as seperators

In this study, LCNNs with varying KL contents (0, 10, 20 or 30 wt% of total network dry weight) were preparad by casting TO-CNF/KL dispersions at 40 °C on PTFE dishes. Following, the networks were hot-pressed to obtain optimized thickness and uniformity together with increased dimensional stability of TO-CNFs The absorption properties were studied before and after the hot-press treatment, and mechanical properties of the networks were mesured both in dry state and soaked in 1 M H_2SO_4 electrolyte. The cross-section morphology, chemical composition and thermal stability of LCNNs are investigated via scanning electron microscopy, fourier-transmission Infrared spectroscopy and thermogravimetric analysis (TGA), respectively. With increasing amount of KL, the absorption of networks in 1 M H_2SO_4 have decreased, with respective values of 384 ± 14, 276 ± 21, 227 ± 19 and 207 ± 25 wt% of dry network weight after hot-pressing. LLCNs exhibited good thermal stability in TGA, with maximum thermal degradation temperatures at ≈245 and ≈300 °C as calculated from decomposition curves, and exhibited dimentional stability up to 250 °C which secured a thermal stability considering device safety aspect. Furthermore, the electrochemical properties were assesed with cyclic voltammetry, galvanostatic charge-discharge and electrochemical impedance spectroscopy tests, and the relationship of device performance and KL amount in LCNNs as seperators was investigated.

By tailoring KL incorporation, we aim to develop a tunable pathway for optimizing separator properties for scalable, greener fabrication of biopolymer-based energy storage devices while demonstrating the multifunctional role of KL in TO-CNF separator performance as alternative to fossil-derived separators.

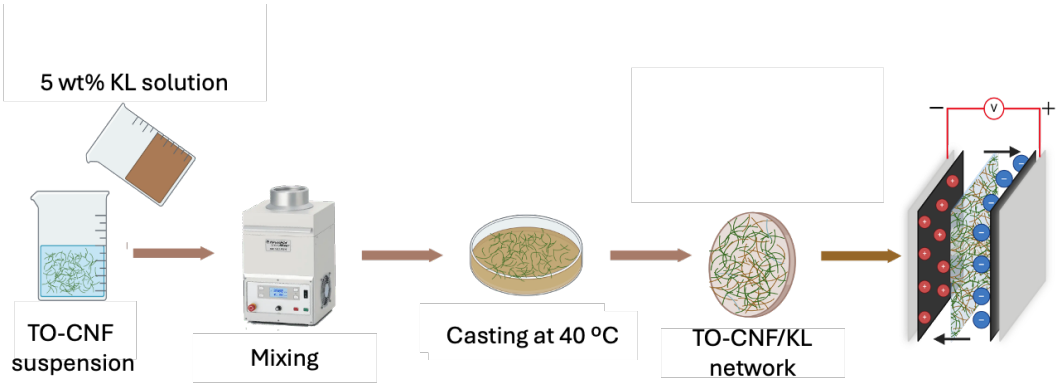

Figure 1. Graphical abstract of preparation of LCNNs as supercapacitor seperators.

[1] S. M. A. Nayem, S. Islam, S. S. Shah, A. Awal, N. Sultana, A. J. S. Ahammad, Aziz A. pp. 403-415, “Biomass-Based Supercapacitors: Design, Fabrication and Sustainability” Editors: Md. Abdul Aziz, Syed Shaheen Shah, John Wiley & Sons, USA, 2023

M33 - Hydrophobization of Wood enabled by Imidazole Derivatives and Water

Sustainable Materials/Circular Economy
Materials & Engineering

Hydrophobization of Wood Enabled by imidazole derivatives and Water

Twaroch, N.*[a], Jusner, P.[a], Gierlinger, N.[b], Beaumont, M. [a], Rosenau, T. [a]

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In the quest of establishing greener and more renewable materials, various esterification approaches have shown promise in creating valuable materials from biomass. Utilizing different esters, biobased polymers can be tailored to desired properties.The preparation of these esters often requires harsh conditions or hazardous chemicals which reduces any benefit of utilizing a renewable raw material.

After investigating acetylimidazole for enabling the acetylation of cellulose fibers [1-2], we turned our attention towards more varied esterification approaches by different imidazole derivatives. Wood provides a simple and elegant matrix, as no resource-intensive pretreatment is required to obtain the raw material. Robustness, adaptiveness and green chemistry are the guiding principles behind our esterification approaches.

We present innovative ways to esterify wood (powder) in the wet or dry state using imidazole or 1,1-carbonyldiimidazole. Acetyl, hexanoyl and benzoyl were selected as acyl moieties. Further, we explore the importance of water in the reaction, Contrary to classical Fischer esterification, where water is often being labelled as “enemy”, processes involving *N*-acylimidazoles are acyl transfer reactions that can well tolerate water or even are promoted by its presence. The established protocols enable uniform material modification as confirmed by Raman imaging, infrared and nuclear magnetic resonance spectroscopy. In addition, we investigate the specific reactivity of lignin and polysaccharides in the wood samples and correlate the chemical modifications with changes in the resulting materials’ hydrophobicity. These versatile methods open new ways toward environmentally friendly and efficient wood modification.

[1] Beaumont, M.; Jusner, P.; Gierlinger, N.; W. T. King, A.; Potthast, A.; Rojas, O. J.; Rosenau, T., *Nat. Commun*. **2021**, 12, 2513.

[2] Beaumont, M., Winklehner, S., Veigel, S., Mundigler, N., Gindl-Altmutter, W., Potthast, A., Rosenau, T., *Green Chem*. **2020**, 22, 5605-5609.

M34 - Hydrogen bond donor additive in cellulose ester films for thermally expandable microspheres

Sustainable Materials/Circular Economy
Materials & Engineering

Hydrogen bond donor additive in cellulose ester films for thermally expandable microspheres

Nejström, M.*[a], Andreasson, B.[a], Wijtmans, R.[a], Sjölund, J.[b], Svensson, T.[a]

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Cellulose based materials have a range of material properties, that can be tweaked even further by the addition of additives to suit specific applications. With the goal to make thermally expandable microspheres (TEMS) of cellulose based materials, the additive is a vital component, that broadens the barrier- and softening properties. TEMS are developed under the trade name Expancel by Nouryon and are used as lightweight fillers and as blowing agents in various industrial fields such as paints, building materials, wine stoppers and many more. With our society increasingly focusing on sustainability, it would be an improvement to have the shell material cellulose based instead of fossil based. In this work, thin films of cellulose esters with various carboxylic acid additives were tested with SEM, DSC, contact angle, gas barrier performance, and directly in the application as TEMS with TGA, TMA and GC-FID. It was concluded that additives that work as hydrogen bond donors are well suited for the task and greatly enhance storage stability of the microspheres. The mechanism behind the hydrogen bond donor phenomenon is thought to be similar to a cross-linking, although less extensive since it is non-covalent. An additional unexpected benefit for the TEMS was the lack of toxic gases and ash during and after burning, which means that the product is also well suited as a sacrificial template, where well defined pores are required. The development of TEMS from cellulose based materials with hydrogen bond donor additives is ongoing and the first generation is on the market as a pilot scale product, named Expancel BIO 100. Going forward, the focus will be on collecting research and industrial input on the prototypes so that it can be developed in a way that is the most beneficial to society.

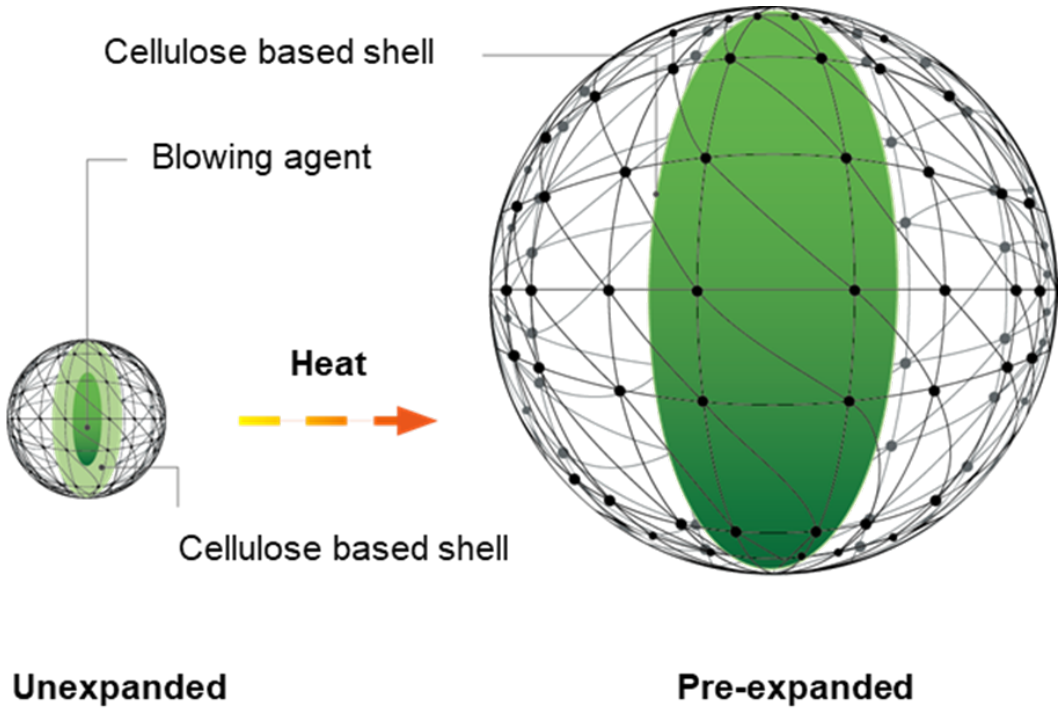

Figure 1. Thermally expandable microspheres with a cellulose-based shell material

M35 - HIERARCHICAL ETHYLCELLULOSE/NATURAL FIBER POROUS COMPOSITE MATERIALS FOR CONTROLLED OXYGEN RELEASE FROM CALCIUM PEROXIDE

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Hierarchical ethylcellulose/natural fiber porous composite materials for controlled oxygen release from calcium peroxide

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Nature-inspired hierarchical materials can be developed using polymers and natural fibers to achieve controlled properties. This study focuses on ethylcellulose (EC) combined with CaO_2 and reinforced with cotton or kapok fibers. The hypothesis suggests that the type of fiber, polymer concentration, and drying method influence material density, which affects O_2 release kinetics in aqueous systems. Ethanol-based EC solutions with fibers were molded and dried using different methods (ambient pressure and under vacuum). O_2 release kinetics in phosphate buffer solution were correlated with the material's apparent density and morphology. Increasing concentrations of EC and kapok fibers resulted in materials with higher densities. Vacuum drying produced less dense materials compared to those dried under ambient pressure. The slower solvent evaporation rate and higher capillary pressure during ambient pressure drying led to a more compact structure. Analyzing the kinetics results, the material combining kapok and ambient pressure drying exhibited the lowest oxygen release rate, consistent with the density results. Overall, the drying method had a stronger effect than the fiber type. The results demonstrate that fiber selection and drying methods can optimize density and O_2 release kinetics.

Acknowledgments

The authors thank the São Paulo Research Foundation (FAPESP) (2023/18116-7) for funding and Région Sud-Provence-Alpes-Côte d'Azur for its support in the acquisition of the MAIA 3 SEM (Research Call 2019).

M36 - ENHANCING IMPACT-RESISTANCE OF RECYCLED POLYPROPYLENE RESINS BY SURFACE COATING WITH AMPHIPHILIC CELLULOSE NANOFIBRILS

Sustainable Materials/Circular Economy
Materials & Engineering

Enhancing impact-resistance of recycled polypropylene resins by surface coating with amphiphilic cellulose nanofibrils

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Material recycle is an urgent issue in the worldwide to establish a sustainable society. The quality of plastic products are supposed to deteriorate in their mechanical properties after recycled. This drawback prevents the promotion of recycling of plastics. At present, the recycled plastics are usually supplied to the thermal recycling process, which emits large amounts of carbon dioxide. Namely, when an effective recycling system such as lowering the deterioration or increasing their strength is achieved, it results in reduction of carbon dioxide emissions.

Recently, Kondo et al. successfully prepared amphiphilic nanofibrils (= ACC-CNFs) by using the aqueous counter collision (=ACC) method[1-3]. This ACC-CNFs are found easily to adsorb surface of the PP particles simply by mixing in their aqueous suspension[4,5]. The PP coated with ACC-CNFs allow embedding 3D-honeycomb frames into their injection-molded products[6]. The amounts of the ACC-CNFs in the PP products were merely 0.03 wt% of PP weight.

According to the previous papers[4,5], ACC-CNFs are preferable to adsorb into PP among conventional plastic resins. Therefore, the above material design using the ACC-CNF/PP particles can be a model system for examining feasibility of a recycling process.

In the present paper, the ACC-CNFs/virgin PP products crushed were used and re-mixed with ACC-CNFs in an aqueous dispersion. After the injection molding, the PP recycled products were evaluated particularly in terms of impact strength. As a result, impact-resistance of the products from the ACC-CNFs/crushed PP particles improved by more than 10% when compared to that of ACC-CNFs/virgin PP products under 40 °C atmosphere. The amounts of the ACC-CNFs contained in the recycled PP products were also 0.03 wt% of the PP weight. Accordingly, this recycling method using a ultratrace amount of ACC-CNFs is feasible to increase in impact-strength of repeatedly recycled PP composites.

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M37 - Growing mycelium-starch composite films by submerged fermentation

Sustainable Materials/Circular Economy
Materials & Engineering

Growing mycelium-starch composite films by submrged fermentation

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Mycelium, a network of microfilamentous structures in fungi, is a natural composite polymer composed of mannoproteins, β-glucans, and chitin.[1] Most previous studies have focused on utilising mycelium's ability to bind lignocellulosic particles to produce mycelium-bound composites by solid-state fermentation.[2] These porous and lightweight materials have demonstrated potential in various applications, including packaging, construction, and insulating materials.[3-5] However, while mycelium-bound composites via solid-state fermentation have been extensively researched, the inherent heterogeneity of this approach compromises the reproducibility of the obtained materials.[6] An alternative approach is submerged fermentation; however, there is limited research on mycelium-based composites produced in this way.

This study investigates the production of mycelium materials produced through submerged fermentation, with corn starch included in the liquid media. Starch is a bio-based, biodegradable polymer that has been extensively studied due to its abundance, film-forming properties, and oxygen barrier properties.[7, 8] Here, we aim to produce a mycelium-based composite by submerged fermentation that integrates the beneficial properties of starch, while also allowing for more scalable processing of the hybrids via filtration that could be applied for packaging applications.

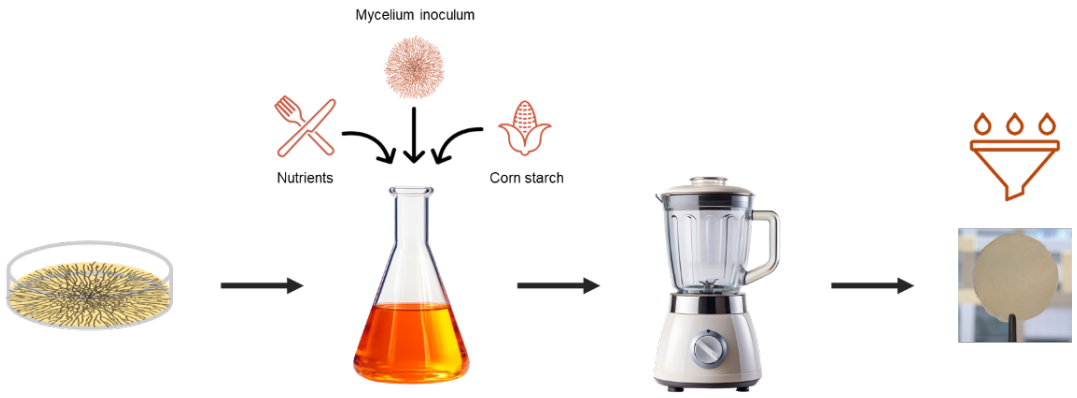

Figure 9 **Figure 1 Schematic representation of the mycelium-based film fabrication process**

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M38 - FUNCTIONALISATION OF CELLULOSE-BASED SUBSTRATES AND FIBRES TO OBTAIN NOVEL MATERIALS: INTERREG F-W-VL VALCELMAT PROJECT

Sustainable Materials/Circular Economy
Materials & Engineering

Functionalisation of cellulose-based substrates and fibres to obtain novel materials:

INTERREG F-W-Vl VALCELMAT PROJECT

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Petro-based materials are omnipresent in daily products, especially food packaging, textiles, composite materials and are associated to environmental problems: plastic-induced pollution. In a context of global warming, the use of renewable non-food biomass resources, to produce reliable and environmentally friendly alternatives to petroleum-based polymers, has become essential. The growing emergency of the subject has made it a matter of increasing interest. The Interreg France-Wallonia-Flanders (F-W-Vl) project called VACELMAT (Figure 1, 2024-2028), meaning VALorisation of CELlulose for MATerial applications, is totally in line with the challenges facing our society. The aim is to offer alternatives to petroleum-based products in 3 industrial areas: packaging, textiles and composite materials. Packaging, particularly food packaging, is a key area of the project. The European Union's Greendeal for 2030 calls for 100% recyclable packaging. In textiles, the EU's strategy for 2030 is to have more textiles that are sustainable, recyclable and free of hazardous substances. For composites, the aim is to offer alternatives to petroleum-based additives.

Figure 1: Operators and Associated Operators involved in the Interreg F-W-VL VALCELMAT project

To achieve this, the VALCELMAT project aims to use cellulose, the most abundant polysaccharide on earth, cost-effectively extracted from plant biomass, as raw material. Cellulose and its derivatives will be modified in an eco-responsible way using sustainable chemistry or enzymatic processes, to confer new functionalities (mechanical, thermal, oil and water barriers, gas barriers, moisture and fire resistance, surface properties) while retaining its intrinsic properties (absence of toxicity and biodegradability). Bulk and surface modifications will be carried out using innovative, eco-environmentally batch and continuous processes, especially reactive extrusion or electrospinning (for textiles), always considering up-scalable processes for industrial applications. The first research focused on the esterification of cellulose (using sustainable chemistry) and ignifigation to confer thermoplastic and surface/functional properties or fire retardancy, respectively. At the end of the project, the best solutions will be tested at prototype and demonstrator.

M39 - Exploring the Chirality of Carboxylated Cellulose Nanocrystals Derived from Waste Cardboard Fibers

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Exploring the Chirality of Carboxylated Cellulose Nanocrystals Derived from Waste Cardboard Fibers

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Abstract

The current work aimed to evaluate the chirality of carboxylated cellulose nanocrystals (c-CNCs) derived from waste cardboard fibers. For this purpose, the waste cardboard fibers were subjected to an initial washing treatment with hot water and then converted into c-CNCs by a direct and efficient oxidation process using ammonium persulfate (APS), without requiring prior chemical pretreatment [1]. A series of methods were used to characterize the properties of the extracted CNCs. The methods included zeta potential for stability and surface charge characteristics, dynamic light scattering (DLS) for size distribution analysis, titration methods for determining surface charge values and carboxyl content, polarized light microscopy (POM) for analyzing chiral nematic ordered phases in water, atomic force microscopy (AFM) for morphological characteristics, attenuated total reflection infrared (ATR-FTIR) spectroscopy for functional group identification, X-ray diffraction (XRD) for crystalline structure investigation, X-ray photoelectron spectroscopy (XPS) for surface chemistry, composition, and functionalization analysis of CNCs was used. The present study aims to propose a stable procedure for c-CNCs extraction from waste cardboard fibers and optimize their surface chemistry to produce chiral nematic phases [2]. We presume that the inherent self-assembly nature of c-CNCs can open up more possibilities for developing value-added advanced functional materials from lignocellulosic waste.

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M40 - Exopolysaccharides from psychrophilic bacteria for icephobicity

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

Exopolysaccharides from Psychrophilic bacteria for icephobicity

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Exopolysaccharides (EPS) are carbohydrate-based biopolymers, secreted by microorganisms in their surrounding environment to support survival and to promote proliferation. The psychrophilic bacteria *Colwellia psychrerythraea* 34H was previously found to produce specific EPS, which are particularly interesting for their cryoprotection activity [1], therefore opening new opportunities of developing innovative materials based on EPS extraction. In this study, we have successfully grown *Colwellia psychrerythraea* 34H by following two different synthetic strategies (batch and bioreactor) and extracted the EPS of interest from subsequent separation steps. The EPS produced were used to prepare monolayers deposited over glass slides and agar-based hydrogels. These materials were tested in their icephobic properties, especially focusing on ice adhesion. Despite the de-icing performance (i.e. reduced ice adhesion) needs further improvements, we believe this is an interesting new approach for the development of biotechnological materials for icephobicity and other applications.

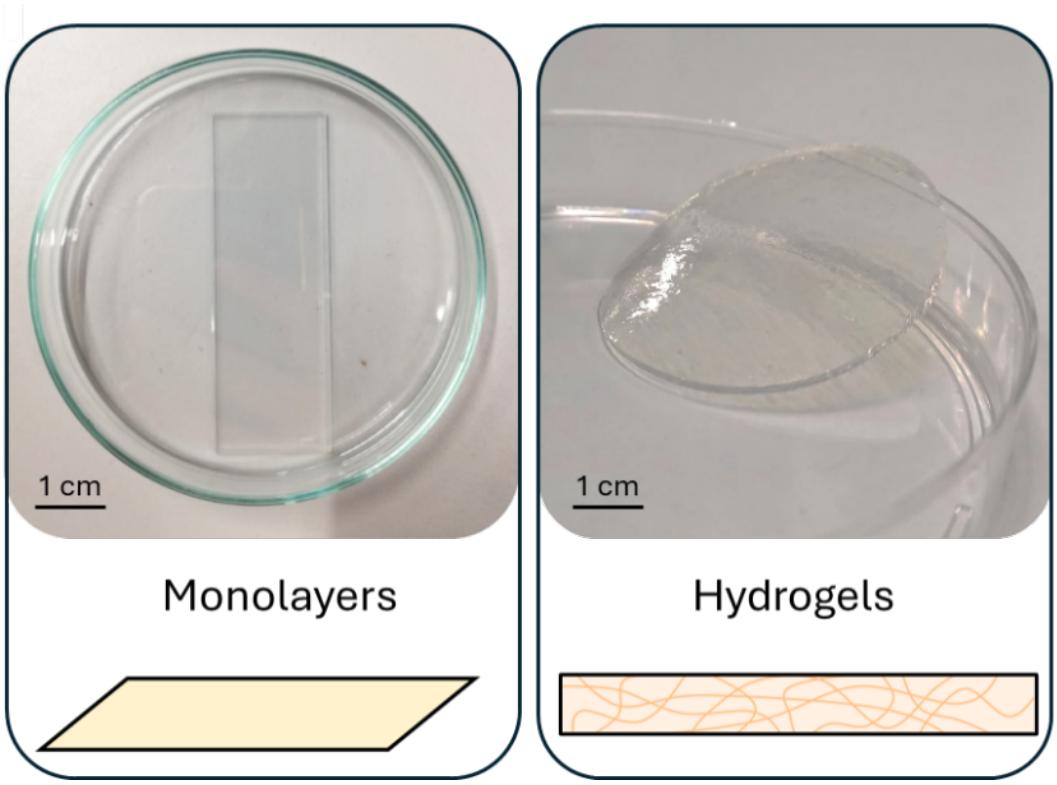

Figure 1. Picture and schematic representation of a glass slide coated with a EPS monolayer on the left, agar-EPS hydrogel on the right.

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M41 - Exopolymers from the fermentation of Schizophyllum commune

Nanostructured Materials
Materials & Engineering

Exopolymers from the fermentation of *Schizophyllum commune*

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The emergence of the bioeconomy has increased the contribution of bio-based products due to their renewable nature [1]. Among these, extracellular secretions from microbial species are of interest due to their material properties, such as oxygen barrier [2].

Schizophyllum commune (*S. commune*), an edible fungal species, produces extracellular substances, including the polysaccharide schizophyllan (SPG) and the mannoprotein hydrophobin. SPG has already been commercialized as a cosmetic ingredient (e.g., in a moisturizing cream from Paula's choice) [3], is actively studied for biomedicine [4], but is less explored in the field of materials science [5].

A major bottleneck in utilizing microbial-derived exopolymers is the high costs associated with conventional isolation processes (e.g., pullulan isolation by ethanol precipitation can cost up to $1608.71 per kg of pullulan) [6, 7], as well as the use of tedious and toxic purification strategies (e.g., Sevag deproteinization) [8, 9]. Furthermore, the harsh purification methods used to isolate polysaccharides from the exopolymer mixture can deteriorate their properties (e.g., alkali extraction of fungal polysaccharides can lead to structural changes) [8]. Specifically, SPG extraction under alkaline conditions ([NaOH] > 0.25 M) can lead to the destruction of its triple helix structure [10].

In this study, submerged fermentation of *S. commune* is used to produce a minimally purified exopolymer stream enriched in SPG, avoiding traditional solvent-based precipitation approaches. The composition and supramolecular structure of our isolated stream are analyzed, and the effect of fermentation time is elucidated. Notably, as *S. commune* matures, not only does the yield of extracellular polymers change, but also their material properties, with implications for the functional applications of SPG-derived materials.

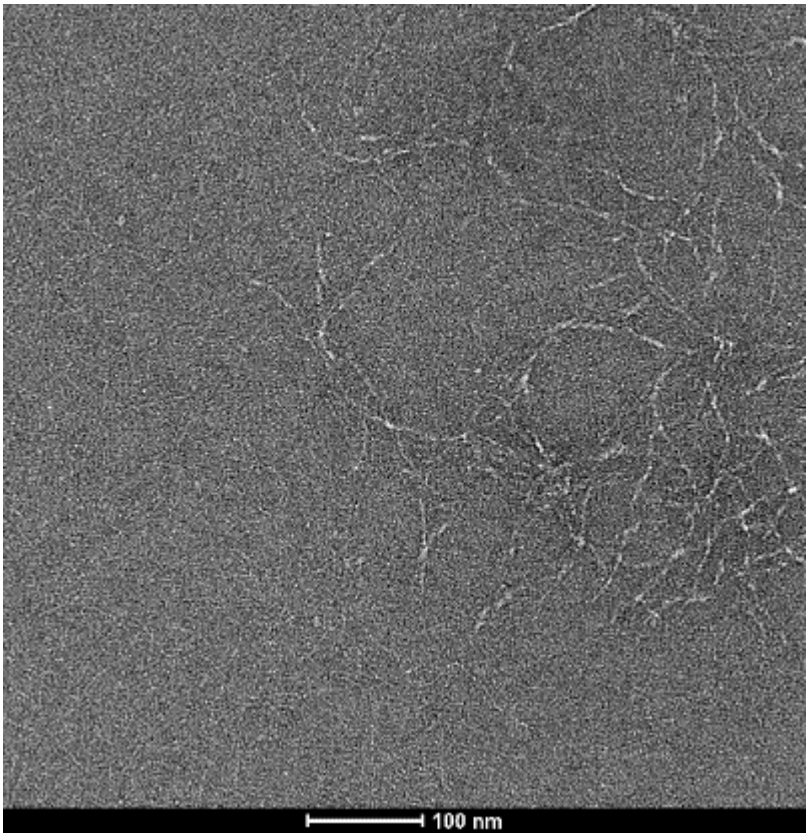

Figure 10 . TEM image of minimally purified extracellular polymers enriched in SPG

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M42 - DURABILITY ASSESSMENT OF BIOCOMPOSITES DEVELOPED IN THE LIFE RESTART PROJECT

Sustainable Materials/Circular Economy
Materials & Engineering

Durability Assessment of Biocomposites Developed in the LIFE RESTART Project

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This work is part of the Life Restart project, co-founded by the European Union[1], which focuses on developing sustainable materials from renewable resources. In this project, bio-pellets made from polybutylene succinate (PBS) and brewer's spent grain (BSG), a polysaccharide-rich by-product of the brewing industry, were produced as environmentally friendly alternatives to fossil-based plastics. Understanding how accelerated and natural weathering influence the mechanical, physical, and morphological properties of such materials is essential to predict their long-term performance[2,3]. In line with this development, the first industrial production site for these materials was set up in Roccavaldina, in the province of Messina (Sicily, Italy). An important aspect of these biocomposites is their durability under natural environmental conditions. To investigate this, PBS/BSG composites (70/30 wt%) were subjected to artificial ageing for 0 h, 300 h, 600 h, and 900 h under controlled laboratory conditions. The materials were prepared by melting compounding and shaped using injection molding. To evaluate their long-term performance, a range of physico-chemical, mechanical, and morphological tests were performed, providing insights into how environmental exposure affects the properties of these biocomposites over time.

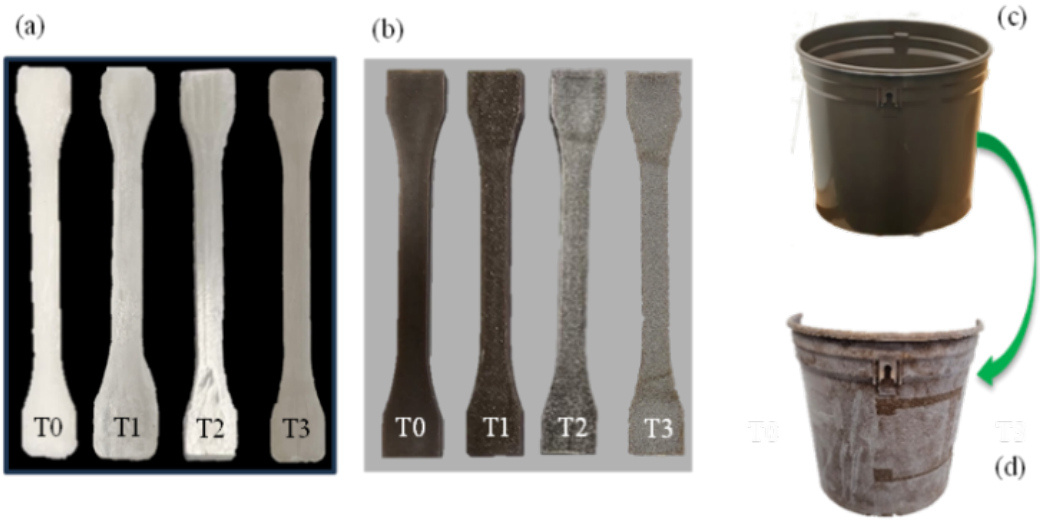

Figure 1.Photographs of neat PBS (a) and PBS-BSG30 (b) dogbone specimens before (T0) and after accelerated weathering (T1: 300 h, T2: 600 h, T3: 900 h). (c) PBS-BSG30 planter as produced and after 18 months of natural outdoor aging (d), highlighting differences in color between accelerated and real-world weathering.

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M43 - ELECTROSPUN CHITOSAN FOR POTENTIAL USE IN FILTRATION AND AS PAPER COATING

Nanostructured Materials
Materials & Engineering

Electrospun chitosan for potential use in filtration and as paper coating

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Chitosan, a biopolymer derived from chitin, has garnered attention for its electrospun nanofibres, attributed to its inherent biocompatibility, biodegradability, and non-toxicity. However, due to its limited electrical conductivity, the electrospinning of chitosan is hindered, impeding consistent fibre formation. Conductive polymers, such as poly(ethylene oxide) (PEO), are commonly incorporated to mitigate this issue.

This study investigated the electrospinning of chitosan/PEO solution, systematically varying the chitosan to PEO ratios from 3:1 to 50:1, utilising 50% and 70% acetic acid solutions as solvents. The objective was to determine the optimal chitosan concentration that maintained uniform nanofibre formation. Results demonstrated that even trace PEO (≤4%) enhanced chitosan electrospinnability, improving nanofiber formation and morphology.

A key limitation of chitosan electrospun nanofibres is their water solubility due to residual acid ions from the electrospinning solution. 5% citric acid was incorporated into the acetic acid solution to enable crosslinking. Subsequently, the nanofibres were subjected to thermal treatment at 115 °C for 15 minutes, facilitating effective crosslinking and mitigating fibre dissolution in aqueous environments.

Consequently, the crosslinked chitosan/PEO nanofibres demonstrated enhanced mechanical strength and stability in aqueous media. These nanofibres exhibited potential for application as filtration membranes for heavy metal sequestration and as coatings for paper substrates, thereby improving their resistance to aqueous and lipophilic substances.

In summary, this study demonstrates the feasibility of producing electrospun chitosan nanofibres with PEO additives. It highlights their potential for advanced filtration and paper coating applications by effectively mitigating solubility limitations through cross-linking.

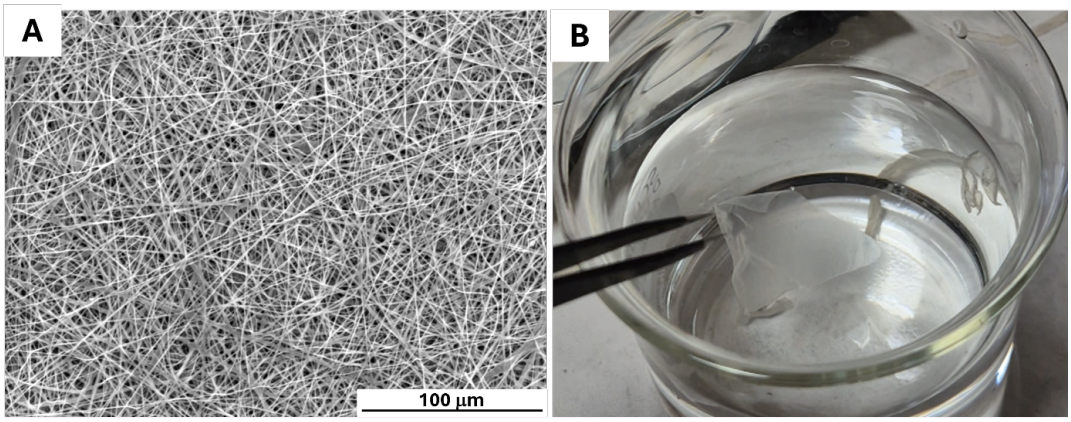

Figure 1. Electrospun chitosan/PEO nanofibres. (A) SEM image of chitosan/PEO fibres at a 10:1 ratio. (B) Water solubility testing after thermal treatment.

This research was funded by the the M-ERA.NET grant agreement No. 958174 “Fully Bio-based Advanced Filtration Systems for Removal of Emerging Pollutants from Water (BAPUR)” Nr. ES RTD/2024/28 and the Project No. lzp-2023/1-0123 “Development of Biopolymer-based Hydrophobic Multi-layer Packaging Material from Biomass Waste Streams”

M44 - EFFECT OF SURFACTANT CONCENTRATION ON CELLULOSE NANO CRYSTAL MICRODROPLET DRYING KINETICS AND BUCKLING

Surface & Interface of Polysaccharide-Based Materials
Materials & Engineering

EFFECT OF SURFACTANT CONCENTRATION ON CELLULOSE NANO CRYSTAL MICRODROPLET DRYING KINETICS AND BUCKLING

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The authors have chosen not to publish this abstract.

M45 - DEVELOPMENT OF CATIONIC CELLULOSE NANOCRYSTALS MATERIALS FOR PHOTOLUMINESCENT APLICATIONS

Sustainable Materials/Circular Economy
Materials & Engineering

development of Cationic Cellulose nanocrystals materials for photoluminescent aplications

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Cellulose nanocrystals (CNCs) are crystalline particles obtained from cellulose fibers by acid hydrolysis treatment and are commonly used in the manufacture of reinforcing materials[1]. CNCs can be surface functionalized at their hydroxyl groups or at their reducing ends, allowing them to be coupled in an aligned manner with luminescent emitters to produce a high-strength luminescent moldable material[2]. The aim of this research is to determine if the emitted photoluminescence is a function of the cellulose source, which affects the crystallinity and crystal size of the initial sample, and the polymorph type (cellulose I, II, III, and IV), which determines the three-dimensional structure, the arrangement of the reducing ends, and the spacing between the CNC chains. CNC I and II were prepared from pine and eucalyptus kraft pulp and functionalized by cationization at their hydroxyl groups and reductive amination at their reducing ends. Finally, the functionalized CNCs were reacted with Rhodamine 6G to obtain photoluminescent materials with different light emission patterns. At present, the results of transmission electron microscopy (TEM) of CNCs I and II from eucalyptus (Figure 1) showed differences in their agglomeration patterns.

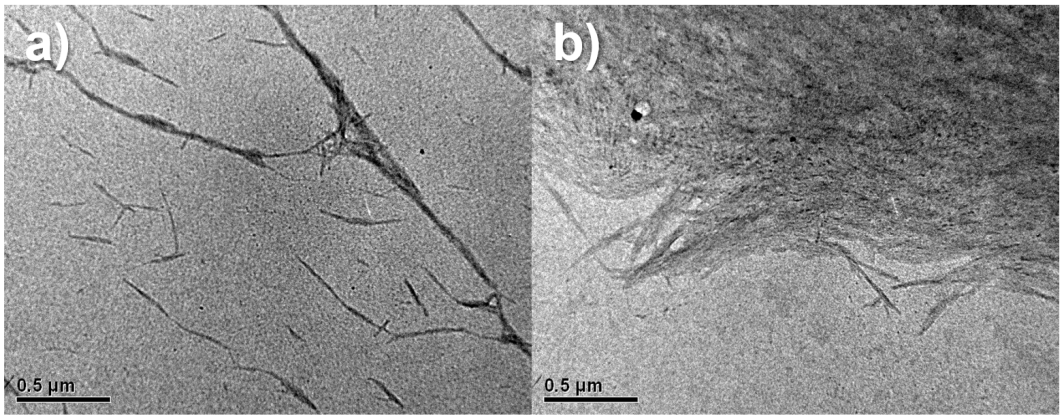

Figure 1. TEM of a) CNC I and b) CNC II

[1] C. Gomri, M. Cretin and M. Semsarilar, *Carbohydrate Polymers* 2022, *294*, 119790.

[2] E. Lizundia, E. Meaurio and J. Vilas in *Grafting of cellulose nanocrystals*, Elsevier, 2016, pp. 61-113; b) H. Tao, N. Lavoine, F. Jiang, J. Tang and N. Lin, *Nanoscale Horizons* 2020, *5*, 607-627.

M46 - CONTINUOUS PRODUCTION OF CELLULOSE NANOCRYSTALS VIA SULFURIC ACID HYDROLYSIS: INTEGRATING LAB-SCALE MEMBRANE TRIALS AND PILOT SCALE ACID RECOVERY

Nanostructured Materials
Materials & Engineering

CONTINUOUS PRODUCTION OF CELLULOSE NANOCRYSTALS VIA SULFURIC ACID HYDROLYSIS: INTEGRATING LAB-SCALE MEMBRANE TRIALS AND PILOT-SCALE ACID RECOVERY

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Cellulose nanocrystals (CNCs) are promising nanomaterials derived from renewable plant fibers, known for their high crystallinity, mechanical strength, and surface reactivity. Traditional sulfuric acid hydrolysis for CNC production is typically conducted in batch mode, necessitating resource intensive steps such as centrifugation, dialysis, and chemical neutralization. These steps not only increase resources consumption but also introduce impurities compromising CNCs purity.

To address these challenges, this study introduces a continuous CNCs production process designed for in-line hydrolysis, CNCs separation, and acid recovery, thereby reducing operational steps and improving scalability. By maintaining continuous flow and recycling acid, the process greatly reduces water usage, avoids contamination of the CNCs, and offers a more scalable route for sustainable CNCs manufacturing.

Prior to scale up, customized polyvinylidene fluoride (PVDF) and crosslinked PVDF membranes were synthesized, which demonstrated remarkable chemical resistance when immersed in concentrated sulfuric acid for extended periods of time (>2 months). These membranes were initially evaluated in dead-end filtration mode to assess their performance.

Following hydrolysis, the resulting super acidic mixture is directed to a crossflow ultrafiltration unit. This effectively separates high-purity CNCs from the concentrated suspension without neutralization or dilution steps. Additionally, it facilitates the recovery of a sulfuric acid-rich stream, which can be recycled for further use or utilized to valorize dissolved sugars.

Integrating this filtration technique, not only streamlines the CNC production process but also enhances product purity and sustainability. The use of Chemically resistant PVDF membranes ensures durability and efficiency in handling harsh acidic environments, contributing to the overall feasibility of continuous CNCs manufacturing.

M47 - CHITOSAN-BASED ADHESIVES FOR WOOD AND ACRYLIC GLASS BONDING

Polysaccharide-Based Adhesives & Sealants
Materials & Engineering

CHITOSAN-BASED ADHESIVES

FOR WOOD AND ACRYLIC GLASS BONDING

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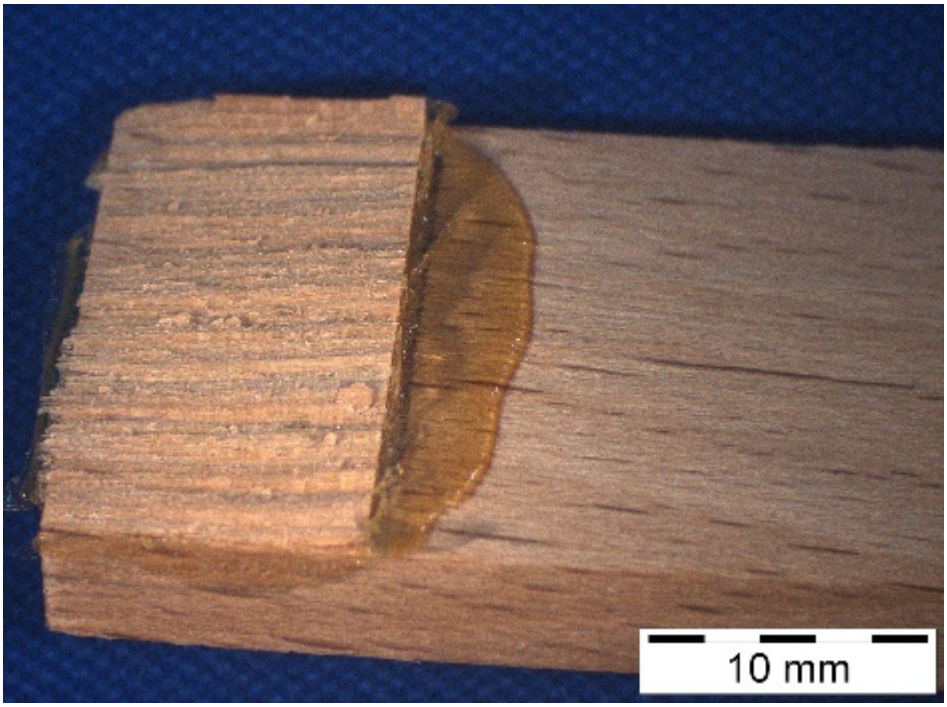
Although there is a wide range of adhesives for different materials, conventional approaches often rely on petrochemical ingredients and organic solvents, which raises concerns about sustainability, especially when bonding to a renewable material such as wood. To address these issues, a fully bio-based, water-based chitosan adhesive for wood bonding has been developed that completely eliminates the need for petrochemical components.

Previous studies have already demonstrated strong adhesion of chitosan-based coatings to wood surfaces [1]. Building on these findings, we investigated its potential as a structural adhesive. The formulation consists of chitosan and itaconic acid, exploiting the natural molecular affinities between chitosan and cellulose. Mechanical tests, including tensile shear-strength measurements, confirmed excellent bonding performance. For spruce and even beech, failure occurred within the wood itself rather than in the adhesive layer. Based on these results, the approach was extended to develop chitosan-based adhesives suitable for bonding acrylic glass and hybrid wood-acrylic glass laminates. Due to the differing surface properties of acrylic glass, additional chemical modifications were introduced to enhance adhesion. While itaconic acid inherently provides unsaturated side chains, alternative polymerising acids were explored to optimise adhesion. The influence of chitosan chain length and different polymerising acids was systematically investigated, leading to the development of a water-based, chitosan-based adhesive for acrylic glass bonding. Tensile shear-strength tests demonstrated strong adhesive performance, with failure occurring within the acrylic glass itself, confirming the high bonding strength of the formulation.

This research systematically investigates different adhesive formulations and evaluates their mechanical performance. The results show that chitosan-based adhesives can bond wood, acrylic glass, and their combinations. In tensile shear-strength tests, failure did not occur in the adhesive layer but within the bonded materials themselves, confirming the high bonding strength of the adhesive.



D

A

B

C

Figure 1. Wood-acrylic glass bondings after curing in the hot press (A), prepared tensile shear specimen for centric clamping (B), specimen in the tensile testing machine (C), and failure in the wood specimen after tensile shear testing of a wood-wood bonding (D).

[1] N. Münstermann, O. Weichold, *Prog. Org. Coat.* **2024**, *194*, 108630.

M48 - Chemical modification of high yield cellulose pulp using the Fenton reaction

Textile, Pulp, Paper & Packaging
Materials & Engineering

Chemical modification of high yield cellulose pulp using the fenton reaction

Poschner, R.[a], Hopf, L.[a], Bakhshi, A.[a], Wagner, A.*[a], Selinger, J.[a,b], Kriesten, I.[c], Meltzer, F.[c], Czibula, C.[a], Harter, T.[a], Eckhart, R.[a], Hirn, U.[a]

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The pulp and paper industry is under increasing pressure to adopt more sustainable and energy-efficient production methods due to rising energy costs and environmental concerns. This study evaluates the use of the Fenton reaction—an oxidative treatment involving hydrogen peroxide and ferrous iron [1]—as a chemical pre-treatment for high-yield Neutral Sulfite Semi-Chemical (NSSC) pulp prior to mechanical refining. The objective was to reduce refining energy demand while maintaining or improving paper strength properties. Fenton-treated pulps were refined in a Jokro mill following reagent application at varying dosages. At optimized conditions, energy consumption during refining was reduced by up to 36% at fixed pulp dewatering resistance (°SR), while tensile index increased by approximately 10% compared to untreated pulp at equal energy input. This indicates that, under specific conditions, the Fenton reaction can improve strength properties without additional energy input. However, high chemical dosages caused fibre degradation, reflected in reduced fibre length and impaired paper strength—up to 20% lower burst index at fixed dewatering resistance—due to deteriorated fibres. At minimal dosages, energy savings of around 10% were achieved without compromising mechanical performance, suggesting a narrow but effective treatment window. No improvements were observed with cationic starch addition to oxidized pulps, which contradicts findings in the literature [2], indicating limited benefit from surface modification under the tested conditions. Overall, while Fenton treatment shows potential for improving refining efficiency, industrial application requires careful optimization and is likely viable under conditions of high energy cost and low chemical price.

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[2] Walter, K.; Paulsson, M.; Wackerberg, E., Nordic Pulp & Paper Research Journal 2009, 24(3), 266-272

M49 - Cellulose-based stretchable biocomposite films with antimicrobial properties imparted through transesterification of sunflower oil

Textile, Pulp, Paper & Packaging
Materials & Engineering

Cellulose-based stretchable biocomposite films with antimicrobial properties imparted through transesterification of sunflower oil

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The heightened emphasis on sustainability and environmental accountability has prompted research into biomaterials and eco-friendly approaches, driven by concerns over the impact of traditional plastics. Bioplastics represent promising alternatives, with their production growing significantly across various applications, particularly in the packaging sector [1]. . However, these materials often face limitations due to low mechanical strength, high water vapor permeability, and higher costs [2]. Additionally, biomaterials can serve as an ideal substrate for bacterial growth, while the toxicity of nanometal particles used for bactericidal action and the increasing bacterial resistance are emerging concerns. Consequently, improving the material's performance without compromising its essential characteristics, such as biodegradability and compatibility through various modifications, while simultaneously achieving antimicrobial properties, is a significant hurdle for biomaterials to overcome.

Ethylcellulose (EC), a well-known derivative of cellulose, is recognized for its inherent hydrophobic characteristics and has become a key contender in the pursuit of sustainable bioplastics [3]. The study focused on the development of EC-based stretchable biocomposite film, which was plasticized with fatty acid ethyl esters (FAEEs) derived from sunflower oil via a transesterification reaction (TER) and reinforced with bacterial cellulose (BC). Two different ways were employed for the BC addition: a bilayer formulation (ECBC-I) and a homogeneous dispersion of BC into EC (ECBC-II). The introduction of FAEEs enhanced the elongation of the films (ECSF) by 124%, effectively disrupting the robust intermolecular H-bonding interactions between EC chains, which are primarily responsible for their inherent brittleness. Furthermore, the tackiness and low toughness of these films have improved with BC, resulting in a notable increase in tensile strength (1.1 MPa) and a reduction in deformation to 30% attributed to the effective reinforcing capabilities of BC nanofibers (Figure 1A). Notably, the biocomposite exhibited superior water barrier properties (160

g/m²/day) (Figure 1B) alongside enhanced hydrophobicity and optical transparency with UV barrier properties. In addition, the antibacterial efficacy of the biocomposite was evaluated in vitro against two multidrug-resistant pathogens, namely *Pseudomonas aeruginosa* and *Staphylococcus aureus*, both of which are frequently implicated in nosocomial infections and food contamination. The biocomposite demonstrated significant bactericidal activity against both bacterial strains after a 4-hour exposure, resulting in a 6-log reduction in colony-forming units (CFU), a finding attributed to the intrinsic antibacterial properties of the FAEEs (Figure 1C-D).

This study utilized renewable materials and a straightforward, cost-effective drop cast solvent evaporation method to produce biocomposites. The results demonstrate the use of FAEEs as a sustainable plasticizer for EC while also exhibiting inherent antibacterial properties, thereby addressing the common challenges associated with the requirement and delivery of additional antimicrobial agents. The study aligns with the principles of sustainable, biodegradable antibacterial approaches and green chemistry. Furthermore, the developed biocomposite shows potential for applications in antimicrobial food packaging and medical devices, such as skin patches, where protection against contamination is crucial.

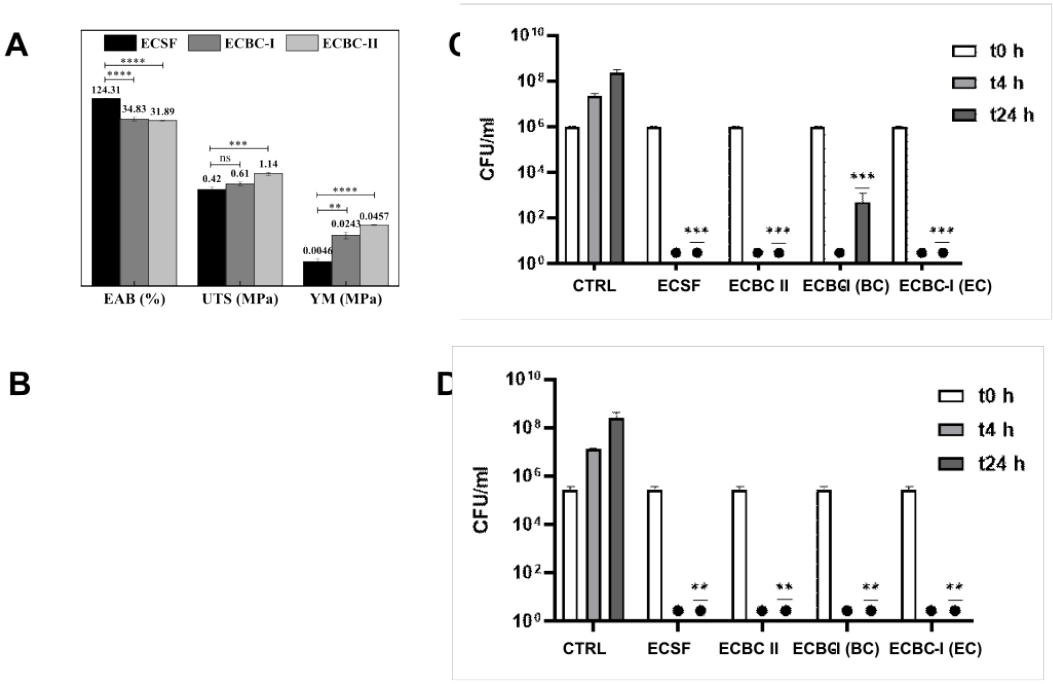

Figure 1. A) Mechanical properties, B) water permeability, the antibacterial assessment for various duration against C) *Pseudomonas aeruginosa,* and D) *Staphylococcus aureus. (*ns- no significance, * P<0.05, **P<0.01, ***P<0.001 and ****P<0.0001).

ECBC-I (BC): BC layer on top and ECBC-I (EC): EC layer on top.

Acknowledgment

The authors acknowledge the support from (1) PON scholarship funded from the resources allocated by the MUR (Ministry of University and Research) with the Ministerial Decree for ESF resources REACT-EU and funds from the University of Salento (2) the Italian Minister of Research with the Ministerial Decree No. 351/2022 – PNRR Mission 4, Component 1, and (3) PNRR–MUR for the funding allocated to Research Initiatives for Innovative Technologies and Pathways in Healthcare and Assistance (Decree No. 9310**,** June 6, 2022), under the ANTHEM project (AdvaNced Technologies for Human centEred Medicine), CUP B53C22006710001.

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M50 - Casting of Ultra-Porous Alginate/Cellulose Nanocrystal Membranes: Fabrication and Characterization

Nanostructured Materials
Materials & Engineering

Casting of Ultra-Porous Alginate/Cellulose Nanocrystal Membranes: Fabrication and Characterization

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Porosity and surface chemistry are key properties of filtration membranes since they define their mass transport and selectivity. Additionally, the surface of membranes can provide specific sites for the immobilization of reactive compounds, like biomolecules or metal nanoparticles.

In this study, we utilized sodium alginate (SA) and cellulose nanocrystals (CNCs) to create hydrophilic and ultra-porous membranes through scalable approaches that can be translated to industrial applications. By systematically studying structure-property relationships, we found that an increased porosity compromised the mechanical strength, presenting a challenge in balancing structural integrity and permeability. Moreover, controlled crosslinking with calcium ions (Ca^{2+}) and a precise adjustment of the crosslinker concentration, crosslinking time, and drying conditions optimized the stability and porosity of the membranes. Infrared spectroscopy confirmed functional group shifts due to crosslinking and scanning electron microscopy showed a regular, opened and interconnected porous structure. Additionally, the membranes exhibited high wet-integrity compared to the pure SA membranes. Ultimately, the presence of both carboxylate and hydroxyl groups on the membrane surface offered the potential to immobilize enzymes and metal nanoparticles for applications in water purification, biomedicine, or catalysis.

M51 - Black Bioinks from Superstructured Carbonized Lignin Particles

Nanostructured Materials
Materials & Engineering

Black Bioinks from Superstructured Carbonized

Lignin Particles

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A renewable source of carbon black is introduced by the processing of lignin from agro-forestry residues. Lignin side streams are converted into spherical particles by direct aerosolization followed by carbonization. The obtained submicron black carbon is combined with cellulose nanofibers, which act as a binder and rheology modifier, resulting in a new type of colloidal bioink. The bioinks are tested in handwriting and direct ink writing. After consolidation, the black bioinks display total light reflectance (%R) at least three times lower than commercial black inks (reduction from 12 to 4%R). A loading of up to 20% of nanofibers positively affects the cohesion of the dried bioink (1 to 16 MPa), with no significant reduction in light reflectance. This is a result of the superstructuring of the ink components, which disrupts particle packing, intensifies colloidal interactions, introduces light absorption, and non-reflective multiple scattering.

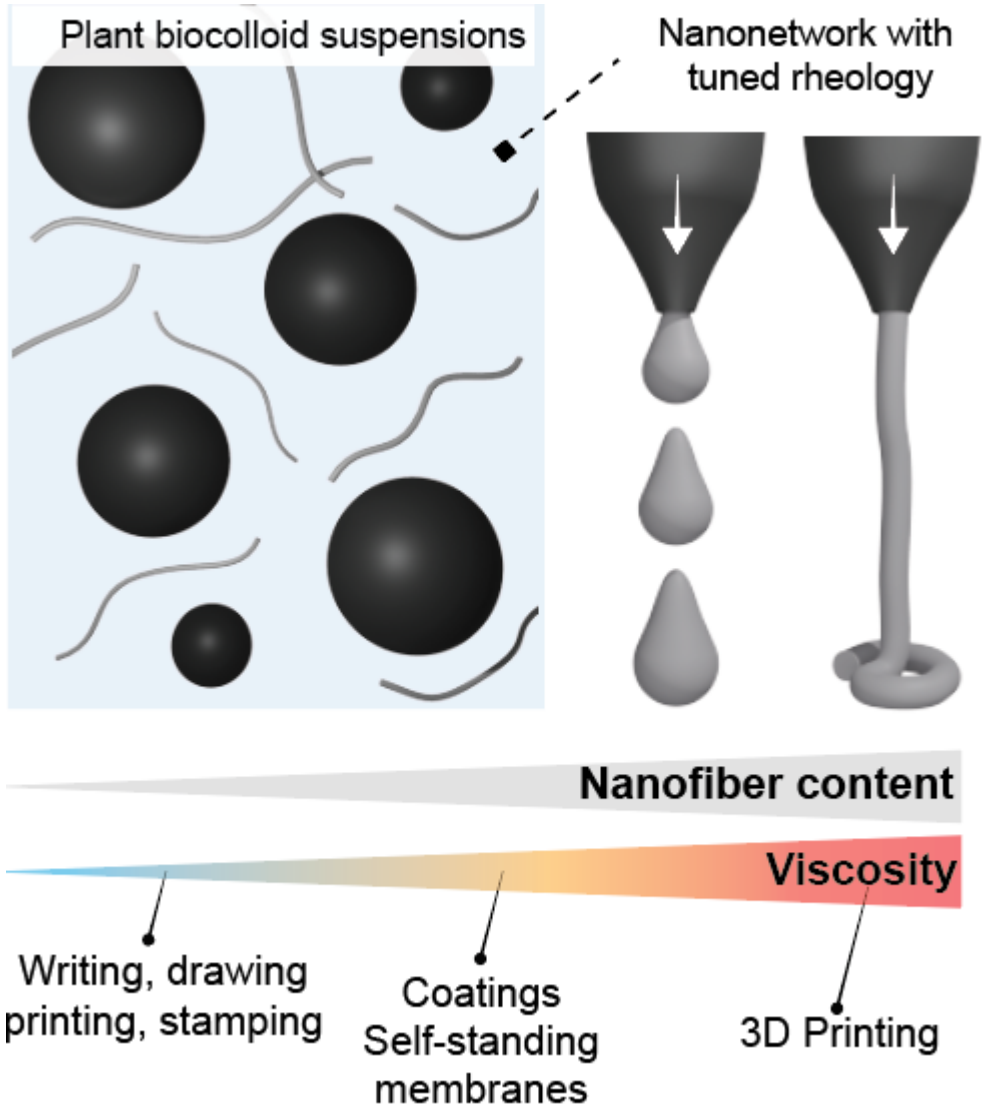

Figure 1. Aqueous suspensions of light-interacting plant biocolloids are used to prepare versatile black bioinks.

M52 - Bacterial Alginate-Based hydrogel reinforced with polysaccharide nanocrystals for water treatment

Environmental Remediation
Materials & Engineering

Bacterial alginate-based hydrogel reinforced with polysaccharide nanocrystals for water treatment

Duarte Serrano, D. [a,*], Waterlot, C.[b], Cézard C.[a], Benjamin B.[c], Barrientos C.[d], Cuneo I.[d], Fuentealba C.[d], Hadad, C.[a], Nguyen Van Nhien, A.[a]

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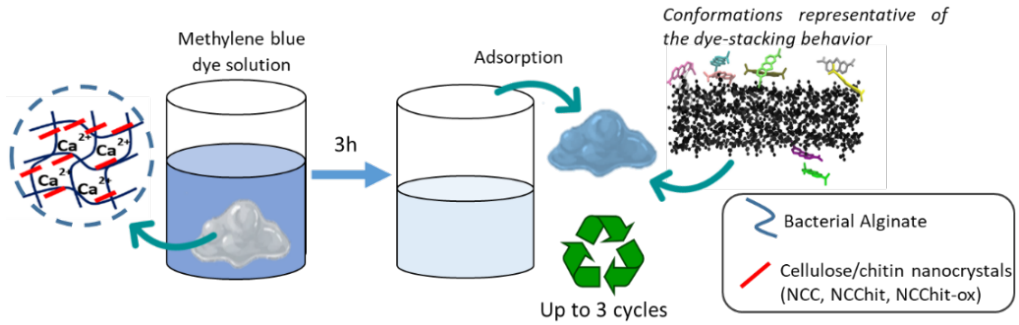

Textile industry has a significant impact on water pollution because of the large amounts of heavy metals, toxic dyes, organic, and inorganic pollutants which generates several environmental problems. Pollution remediation remains a major challenge, highlighting the need for efficient and cost-effective solutions.[1] In recent years, biopolymer-based hydrogels have been investigated to provide a sustainable, efficient, and eco-friendly solution for industrial dye removal.[2] Incorporating nanomaterials into hydrogels can enhance the adsorption capacity of these materials due to the high specific surface area of nano-objects.[3]This study compares first the effectiveness of nanomaterials extracted from cellulose and chitin in Congo Red and Methylene Blue that are the two dyes most commonly found in wastewater.[4] The best sorbent exhibits the highest Langmuir constant (KL) and a maximum adsorption capacity of methylene blue (MB) dye at 96.5 mg/g, with over 92.5% removal efficiency for all concentrations, as confirmed by molecular modeling. These nanomaterials were then incorporated into bacterial alginate-based hydrogels for MB adsorption. Among the evaluated

isotherms, the adsorption experimental data best fit the Langmuir model ($R^2 = 0.9547$). Kinetic data suggest that the adsorption process follows a second-order mechanism ($R^2 = 0.977$). The hydrogel demonstrates excellent reusability, maintaining high adsorption efficiency across multiple cycles.

Adsorption

Adsorption

Methylene blue

dye solution

Congo red dye solution

b

Figure 1. Polysaccharide-based hydrogels formation.

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(2) Malatji, N.; Makhado, E.; Modibane, K. D.; Ramohlola, K. E.; Maponya, T. C.; Monama, G. R.; Hato, M. J. *Nanomaterials and Nanotechnology* **2021**, *11*, 184798042110394.

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(4) Waterlot, C.; Duarte-Serrano, D.; Hadad, C.; Jamali, A.; Van Nhien, A. N. *Chemosphere* **2025**, *377*, 144311.

M53 - AN INSIGHT INTO THE MOISTURE INDUCED CHANGES IN CELLULOSE DERIVATIVES

Sustainable Materials/Circular Economy
Materials & Engineering

An insight into the moisture induced changes in cellulose derivatives

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Cellulose, the most abundant biopolymer in the world, is naturally available and can act as a starting material for various chemical modifications that enable it to take the place of fossil-based materials. Cellulose derivatives, synthesized through the modification of cellulose find their applications in different fields such as food, pharmaceuticals, barrier materials, paints and coatings, packaging etc. An obstacle that retards the widespread usage of cellulose derivatives in industrial applications is moisture and its effects. Cellulose derivatives can absorb moisture and certain cellulose derivatives such as hydroxypropyl methyl cellulose dissolve in water. Even though the interactions of water with cellulose is well studied, there is still a lack of understanding about the interactions between water and cellulose derivatives that are widely used in commercial applications. Therefore, the focus of this study is to gain additional understanding on the driving forces behind the interactions that occur in presence of moisture and how the behaviour of cellulose derivatives possessing different chemical substituents changes. Dynamic vapor sorption measurements will be performed to analyse the water sorption of the materials at different relative humidities and using the data obtained, water sorption kinetics will be investigated. Further, x-ray scattering and dynamic mechanical analysis will be carried out at different humidities to gain understanding about the influence of moisture absorption on the structural changes and polymer chain mobilities, respectively. Additionally, chemical characterizations such as Fourier-transform infrared spectroscopy will be performed to get an idea on the chemical interactions in presence of moisture. This study will prove to provide a holistic understanding on the water interactions in the most prominently used cellulose derivatives.

Keywords: Cellulose derivatives, water sorption, relative humidity, structural relaxations.

M54 - A physical-mechanical study of bio-composites based on lignocellulosic agri-food waste and PBAT/PLA

Sustainable Materials/Circular Economy
Materials & Engineering

A physical-mechanical study of bio-composites based on lignocellulosic agri-food waste and PBAT/PLA

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Abstract

The increasing environmental problems caused by traditional plastics and the urgent need for eco-friendly materials have led to an increasing search for biodegradable polymers with improved performances. This study investigates the development and characterization of biodegradable biocomposites composed of a blend of PBAT/PLA as matrix, added with 30% of lignocellulosic agro-food fillers, including Beer Spent grain (BSG), olive pomace (OP), coffee silver skin (CSS) and mandarin pomace (MP). The aim is to valorize organic residues while improving the functional performance of biopolymers for sustainable applications.The biocomposites were characterized by rheological (melt flow rate, mixing torque), thermal (TGA, DSC) and mechanical (tensile tests) properties, and surface characteristics (contact angle, roughness).

In general, the biocomposites showed higher stiffness, tensile strength and lower deformability compared to PBAT/PLA. However, the mechanical values remain appreciable for "Reuse-Design-Applications".These results highlight the potential of agro-food waste as an effective filler for bioplastics. The study supports the principles of circular economy by transforming food industry by-products into value-added materials, offering a viable strategy to reduce fossil-based plastic pollution and promote sustainable material innovation [1].

Figure 1. Photographic views of lignocellulosic agri-food wastes (top row) : Brewers' spent grain (BSG), mandarin pomace (MP), Coffee silverskin (CSS), and olive pomace (OP). Corresponding bio-composites based on these agri-food wastes and PBAT/PLA are shown in the bottom row, labeled as PBAT/PLA/BSG, PBAT/PLA/MP, PBAT/PLA/CSS, and PBAT/PLA/OP, respectively.

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M55 - ALL-CELLULOSE HYDROGEL WITH ULTRAHIGH STRETCHABILITY EXCEEDING 40000%

Nanostructured Materials
Materials & Engineering

All-cellulose hydrogel with ultrahigh stretchability exceeding 40000%

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While cellulose-based stretchable hydrogels have been extensively explored in recent years, all-cellulose hydrogels continue to face the limitation of low stretchability (less than 250 %). Herein, for the first time, we fabricate an all-cellulose hydrogel with ultrahigh stretchability that can exceed 40000 % strain. By ring opening reaction on cellulose anhydroglucose unit rings, secondary hydroxyls are converted to primary hydroxyls, enabling enhanced chain flexibility, and facilitating the formation of abundant . As a result, the obtained hydrogel displays remarkable characteristics, including record-high stretchability (44200 %), rapid self-healing property (within seconds), and the unique ability to form cellulose fiber. With simple drawing, a smooth and flexible cellulose fiber can be obtained, demonstrating good processability and a high of 226 MPa. Furthermore, the all-cellulose hydrogel can function as a human motion sensor and electrocardiogram electrode for monitoring physiological signals. This simple yet highly effective method will not only propel the advancement of ultrastretchable all-cellulose hydrogels but also create new possibilities for wearable device applications.

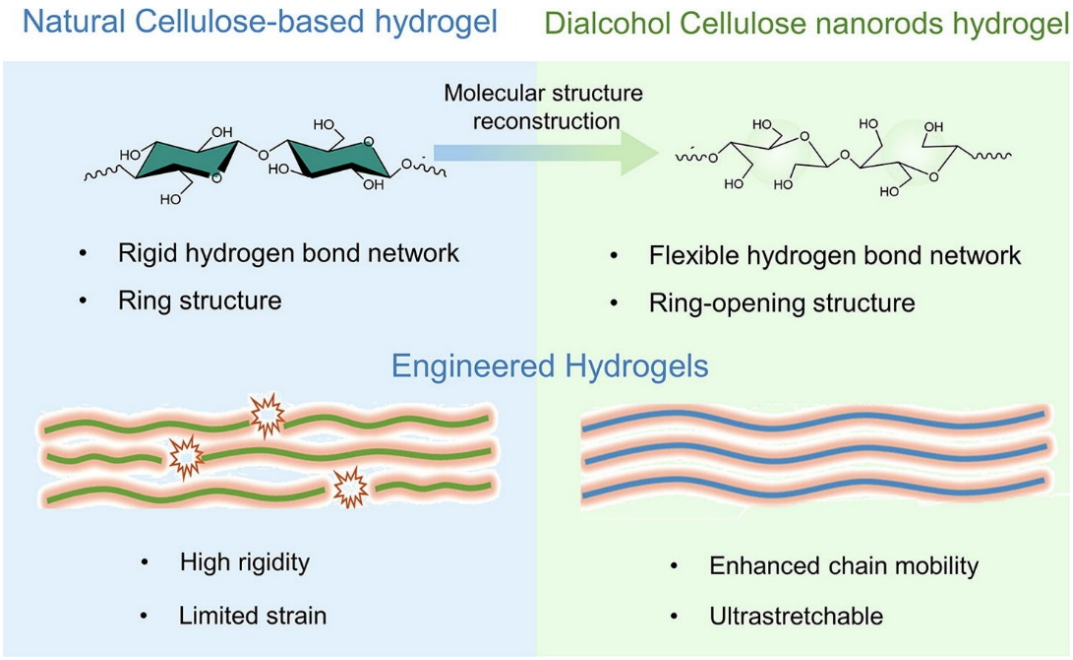

Figure 1. Maximum one figure or table

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