BOOK OF ABSTRACTS

77. BHT - FREIBERGER UNIVERSITÄTSFORUM 2026

FREIBERG FORUM BIOBASED MATERIALS

8th of June

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Oral abstracts

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From Biotechnological Residues to Biodegradable Printed Circuit Boards: Aspergillus niger Mycelium as a Structural Support Material

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The electronics industry urgently seeks sustainable, biodegradable alternatives to conventional substrates for printed circuit boards (PCBs) to reduce the environmental impact of electronic waste and CO_2 emissions. Here, we introduce a biobased, plastic-like material derived from *Aspergillus niger* mycelium, Animat_{RT}. This material is produced from residual biomass generated in industrial citric acid production, offering a circular-economy approach. The raw mycelial biomass, consisting of spherical pellets, is processed via mold casting and air-drying, consolidating the pellets into a dense, plastic-like monolith (1.23 g cm^{-3}).

When formed into sheets, Animat_{RT} serves as a viable substrate for low-complexity PCB fabrication, allowing for direct ink writing and manual soldering of electronic components. Although its electrical properties are lower than those of FR-2 (flame retardant 2), a common, low-cost PCB laminate made of paper bonded with a phenolic resin, it remains suitable for low-frequency and proof-of-concept applications and, on average, has 56% lower embodied carbon. The mycelium boards disintegrate in water, allowing recovery of operative electronic components, whose functionality was demonstrated by re-soldering them onto a conventional PCB. The material exhibits high mechanical performance, with compressive strengths of up to 121 MPa, a flexural modulus of 2.3 GPa, and a flexural strength of 30 MPa. It is fully biodegradable (ISO 20200), redispersible in water, has low flammability, and favorable thermal insulation properties (0.21 W $(mK)^{-1}$). Heat treatment at 120°C enhances the mechanical properties, improves water resistance, and slows biodegradation. This study demonstrates the first use of biotechnology–derived *A. niger* mycelium as a biodegradable substrate for PCBs, addressing circularity and end-of-life challenges in electronics.

Polysaccharides – basis for green products

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Polysaccharides represent not only the most abundant renewable resource but also a promising foundation for sustainable products. They possess remarkable structural diversity and functional versatility. In addition to naturally occurring polysaccharides like cellulose, starch, and xylan, biosynthetically produced variants such as pullulan and 1,3-glucan are also available. This offers the opportunity to precisely design their molecular structure and, consequently, their material properties.

It is puzzling that, to date, commercial applications have almost exclusively involved converting cellulose into a few derivatives, typically under heterogeneous conditions. It has become clear that in such processes, the reactivity is highly dependent on the polysaccharide's structure, even though the reactive site is consistently the hydroxyl group.

The chemical modification of polysaccharides through green processes is key to unlocking the full potential of this biopolymer class. In this context, researchers at the Friedrich Schiller University of Jena have spent two decades fundamentally studying various products and chemical pathways. Now, Posanova GmbH (https://www.posanova.de/) is working to translate this extensive knowledge into commercial applications, which will be briefly discussed here.

Novel long-chain starch esters with thermoplastic properties, for instance, show significant potential for hydrophilizing paper and board. Furthermore, cellulose tosylates and phenylcarbonates with different aromatic ring substituents are promising and stable intermediates for designing functional materials, including a broad variety of so-called "amino celluloses." Today, amino celluloses are already used as active layers for antibody binding in bioassays and as anti-greying agents in detergents.

However, the modification pathways differ significantly. For tosylated polysaccharides, further nucleophilic substitution is limited to intermediates with primary tosyl groups, as secondary tosylates are non-reactive. This limitation, on the other hand, enables regioselective modifications. In contrast, with polysaccharide phenyl carbamates, any position on the polymer backbone is reactive and can be modified via aminolysis. This allows for the straightforward synthesis of products with a high density of functional groups.

Surface Functionalization of Soft Matter via Solid-State Adsorption: From Molecular Interactions to Functional Material Design

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Surface modification is a fundamental requirement for expanding the functional applications of cellulose-based materials. Conventional chemical approaches occurs with limited accessibility, harsh reaction conditions, and poor control over substitution. Solid-state adsorption offers a compelling alternative, enabling surface modification of a substrate by forming a strongly and irreversibly adsorbed polymer layer, the so-called Guiselin layer, without surface pre-activation or aggressive processing conditions. We demonstrate the feasibility of this approach across a range of lignocellulosic substrates, including cellulose nanopaper, textiles, and native wood. Stable Guiselin layers of polystyrene (PS) and poly(lactic acid) (PLA) were validated with adsorption thicknesses of a few nanometers, tunable through polymer type, molecular weight, and processing temperature. Critically, solid-state adsorption selectively engineers the surface while fully preserving the intrinsic bulk properties of the substrate. As a representative example, PLA-modified textiles exhibit water contact angles of ca. 150°, demonstrating effective substrate hydrophobization. Extending this strategy to pristine wood without delignification, we achieved a hydrophobic exterior via an irreversibly adsorbed polymer layer less than 10 nm thick. The resulting wood-based energy generator (20 × 20 × ~0.6 mm^3; longitudinal × tangential × radial) produces output voltages of up to 0.6 V with stable performance sustained over more than 24 hours of cyclic compression at 35% relative humidity. Collectively, our work establishes solid-state adsorption as a promising, mild, and versatile platform for surface engineering of functional lignocellulosic materials.

Collagen – An Animal based Biomaterial with exceptional properties

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Biobased polymers comprise polysaccharides, polynucleotides and proteins. While the structural polysaccharide cellulose is the main component of plants, chitin is that of lower animals and fungi. Polynucleotides are not a mass polymer but a biological information storing system. The protein family of collagens is the main structural building polymer of higher animals. Collagens are the dominating part of the extracellular matrix and connective tissue and therefore the most important structural component of bone, animal skin and organs. As fibrillar proteins collagens show unique material properties. The protein sequence of around thousand amino acids and specific posttranslational modifications of proline to hydroxyproline lead to the building of triple helices (300 nm), fibrils and finally biological tissue. Then, the properties comprise a specific mechanical stability as well as biological and thermal behaviour. Collagen based materials have been used by humans for technical, fashion, food and medical purposes for thousands of years in different processing states [1].
Today, much is known about the structure and the properties of collagen. However, it remains a challenge to produce collagen biotechnologically by microorganisms to prevent the use of animal based materials. While manufacturing of single peptide chains and as well triple helices seem to be possible, the generation of tissue can only be achieved in animal cell culture.

Literature:

[1] Meyer, Michael. „Processing of Collagen Based Biomaterials and the Resulting Materials Properties“. *BioMedical Engineering OnLine* 18, Nr. 1 (2019). https://doi.org/10.1186/s12938-019-0647-0.

Recent developments pertaining to the structural characterization of cellulosic materials using x-rays

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The method for determining absolute polymer crystallinities that considers all typical contributions to detected x-ray intensities was devised by Ruland and made more efficient by Vonk. [1,2] However, as pointed out by Vonk, texture and -to a lesser extent- the choice of the momentum transfer range over which the method is applied may introduce systematic errors that are carried forward into the results. Hence, a systematic study of these effects was recently undertaken by the author, confirming and quantifying Vonk's prediction. [3]
Efforts are underway to alleviate these shortcomings: By changing the extrapolation algorithm to a more robust variant, [4] the accuracy of determined crystallinities was greatly improved. [5] In detail, the results obtained for Avicel PH-101 and a commercial poly(hydroxybutyrate) under greatly varying measurement conditions in reflection and transmission were brought into agreement with values determined by nuclear magnetic resonance spectroscopy or differential scanning calorimetry within the respective measure of uncertainty.

Another improvement concerns the determination of superstructural features in native cellulosic assemblies, exemplified by wood. Here, the most commonly employed model for scattered intensities considers the equatorial intensities from packed microfibril assemblies. [6] Other salient features such as the microfibril angle, the proportion of non-oriented fibrils, or scattering from non-cellulosic polymers or larger-scale features are typically analyzed by adjunct methods, such as the consideration of intensities along the azimuth normal to the fibril axes or the usage of simple distribution functions to cover a number of unknown contributions.
However, in wide-angle scattering with a point beam, the recorded scattering vectors form a cone that does not, or only partially includes the meridional direction along the fibril long-axes.
By using of a threedimensional model and parametrization of its orientation, it was possible to separate, determine, and model more closely all aforementioned contributions, based on their occurrence in reciprocal space.

Literature:

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Recreating Spider Cuticle: Tailoring Protein and Chitin Co-Assembly into Sustainable Bio-Inspired Materials

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Advancements in materials have historically driven technological progress and improved quality of life. However, current methods of material production are fueling the climate crisis through significant greenhouse gas emissions and the accumulation of non-degradable waste. With a growing global population and rising energy demands, the need for sustainable and biodegradable materials has never been more pressing.

Human technology relies on compositional complexity, often impeding recyclability, whereas biological organisms produce a remarkable diversity of materials from a limited set of building blocks. The arthropod cuticle exemplifies this: a versatile composite of chitin and proteins that achieves functions ranging from mechanical protection to structural colouration through architectural variation alone [1, 2]. By understanding the design principles of biological materials, we can develop sustainable materials that match or surpass conventional alternatives.

Inspired by the spider cuticle, where variation in cuticular protein composition tunes both mechanical and hydration properties, we have developed chitin-protein composites by incorporating recombinant proteins containing chitin-binding domains (CBDs) into the assembly of chitin nanocrystals (ChNCs). By varying the protein sequences, we aim to modulate the material properties and hydration stability of the resulting films, establishing a materials library with tuneable mechanical performance. This bio-inspired approach presents a pathway towards biodegradable, durable, and sustainable materials with the potential to replace conventional fossil fuel-based plastics.

Literature:

[1] Y. Politi et al., The Spider Cuticle: A Remarkable Material Toolbox for Functional Diversity. *Philos. Trans. R. Soc. A* 2021, 379, 20200332.
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Use of the whole hemp plant as a source of raw materials for regional and sustainable building materials

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In times of climate change and ever-rising energy costs, pressure is mounting on the construction industry, which is responsible for a significant proportion of CO_2 emissions due to its energy-intensive processes. In particular, the production of mineral and synthetic building materials releases large quantities of climate-damaging emissions [1]. To reduce these emissions, the use of natural and renewable raw materials as building materials is increasingly coming into focus. By acting as carbon sink, the resulting building materials can contribute to a more climate-friendly construction sector. Further arguments in favour of natural building materials include regional availability and the associated strengthening of regional value chains, as well as the conservation of limited fossil resources.

One example of a suitable regional and renewable raw material is industrial hemp. Because of the naturally occurring hemp fibres, these plant fibres offering high tensile strength are well suited as a sustainable building material. Due to the high biomass production during the plant's growing season and its low requirements on soil quality, large quantities of this raw material are available not only in Saxony [2]. Various hemp-fibre-based building materials are already on the market and freely available. However, the offered products mostly consist of processed, pure hemp fibres, which are obtained through a complex and multi-stage process and account only for a fraction of the total available plant biomass. Therefore, the plant's full potential remains untapped.

Consequently, a number of research projects at ITUN (e.g., project "*HAsys*", funding: "Nachhaltig aus der Krise" SAB, 01/2022 - 12/2022; project "*Development of a correlation model for the production of insulation boards from plant residues*", funding "Zukunft Bau" BBSR, 12/2023 - 08/2026) have investigated different ways of utilising the whole hemp plant for the production of building materials. A straight forward process was developed, in which the raw material is first comminuted through an intensive, but non-fractionating defibration step and afterwards converted into building materials using various agglomeration techniques. In doing so, the use of synthetic additives, as is common with commercial materials, can be consciously avoided. Applying high-pressure press agglomeration, rigid fibreboards were produced as an alternative to plasterboards or MDF boards. Applying medium-pressure agglomeration, e.g., pelleting, gives granules for insulation purposes on the other hand. Fig. 1 shows these two exemplary building materials produced in a possible installation scenario, illustrated using a display wall. Current research is focusing on the production of low-weighted insulation mats, or, respectively, boards to expand the potential range of applications for the hemp plant in the construction industry. The contribution gives an detailed overview on the three building material described before made from the hemp whole plant.

Figure 1: Rigid hemp fibreboards and granules in a display wall

Literature:

[1] Hild, Jonathan; Cernicky, Jan: CO2-Grenzwerte im Bausektor. Ein ordnungspolitisch gerechtfertigter Eingriff? Sankt Augustin, Berlin: KAS.

[2] Veronika Schöberl, et. al.: Hanf zur stofflichen Nutzung. Stand und Entwicklungen. In: Berichte aus dem TFZ, Vol. 68.

Development and Characterisation of recyclable bonding processes for bioplastics

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One part of the project EMProBio focuses on developing an energy- and resource-efficient, adhesive bonding process for composite made of biogenic fillers based on wood fibres with metals (e.g. components in vehicle interiors). The aim is to investigate the technological conditions under which such a metal-plastic composite can ideally be produced without the usage of fossil fuels and to study the resulting composite properties. In further steps the energy- and resource-efficient material separation at the end of the product lifecycle will be examined in order to achieve the most complete possible return of the raw material cycle.

To determine the suitability of the biogenic plastic polylactide for adhesive applications, its properties were investigated in relation of manufacturing process and the degree of filling, and compared with those of the fossil-based plastic polypropylene. The use of bio-based adhesives was also included and compared with conventional adhesives in order to enhance sustainability.

The results show that the thermal properties such as thermal resistance, melting temperature and melting enthalpy are strongly influenced by the biogenic content. Additionally, differences between additively manufactured and injection-molded plastics were identified. As the degree of filling increases, the water absorption and the surface roughness of the selected plastics also increases. On the other hand, the wettability can only be influenced through various surface treatment techniques. The adhesives tested were thermally stable within the temperature range examined. Similarly, with regard to water absorption, no direct correlation was observed between weight gain and the type of adhesive and biogenic content.

Metal-Organic Framework (MIL-53 Al) Functionalized Bamboo-Derived Hydrochars for Fluoride Removal in Aqueous Media

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Excessive fluoride contamination in drinking water, arising from both natural geochemical processes and anthropogenic activities, poses a significant threat to environmental safety and public health, particularly in developing regions. This challenge necessitates the development of efficient, sustainable, and low-cost adsorbent materials for water treatment. [1]

This study reports the synthesis of a sustainable bio-based adsorbent by functionalizing bamboo-derived hydrochar with metal organic framework - MIL-53(Al) to enhance fluoride removal from aqueous systems. The synthesized material was characterized using Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), and Thermogravimetric Analysis (TGA) to confirm successful functionalization and assess structural stability. [2-3]

Batch adsorption experiments were conducted to evaluate the effects of contact time, adsorbent dosage, initial fluoride concentration, solution pH, water matrix, and temperature. The results demonstrated a maximum fluoride removal efficiency of 95% under optimal conditions, with equilibrium attained within 60 minutes at an adsorbent dosage of 0.625 g/L. Adsorption performance was enhanced at low pH (pH 1) and in freshwater matrices due to reduced ionic competition. Kinetic and isotherm modeling using the pseudo-second-order model, Langmuir, and Toth isotherms indicated that chemisorption governs the adsorption process. Thermodynamic analysis revealed that the adsorption is spontaneous and exothermic, highlighting the material's suitability for practical applications. [2-3]

Furthermore, application to real mine water samples showed a maximum fluoride removal efficiency of 99.62%, demonstrating the excellent performance and potential of the synthesized composite for sustainable water purification.

Literature:

[1] Esitsakha, A. et al., Physico-chemical, Microbiological, and Ion Assessment in Underground and Surface Water in Machakos County, Kenya. Water, Air, & Soil Pollut. 2024, 235, 174.
[2] Sharma, H. B. et al., Engineered biochar/hydrochar derived from organic wastes for energy, environmental, and agricultural applications. Clean Technologies and Environmental Policy, 2024. 1–35.
[3] Derbe, T., Synthesis of a zeolite-a/MOF-5 composite for the defluoridation of groundwater. RSC advances, 2025, 15(19): 15200-15217.

Poster abstracts

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Fungal Mycelium from *Aspergillus niger* for Technical Materials: Production and Coating

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European biotechnological citric acid production generates in excess of 200 kilotons of *Aspergillus niger* mycelium on an annual basis, a promising resource for sustainable materials. It may reduce dependence on fossil-based plastics.

Mycelium materials are sensitive to water. To address this, we investigated typical water- and solvent-based acrylic, alkyd, hybrid and PU coatings in terms of their resistance to splash water using contact angle tests, and their water uptake behaviour. Four coatings increased the contact angle from 50° to 60°, which is still too hydrophilic. However, after one minute, the contact angles for two of the coatings had decreased to 45° and 55° respectively, whereas the contact angle on pure fungal mycelium had decreased to 35°. These two coatings reduced the water uptake at 99 % relative humidity and 21 °C in one week from 28 % to 16 %.

To allow for a quicker processing, the heat pressing of mycelium biomass was investigated, varying the water content of the biomass, duration and number of pressure relief. A water content of 50 % and multiple pressure relief yielded the most promising results.

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.

Cellulose Derivative-Based Optical Fibers Produced by Melt-Spinning

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The development of sustainable polymer optical fibers from renewable resources is gaining increasing attention due to environmental concerns associated with fossil-based plastics. Cellulose and its derivatives are promising candidates for short-distance optical transmission. However, cellulose-based optical fibers are typically produced via solution-based spinning processes that rely on solvents and are therefore limited in scalability. In contrast, industrial POFs are usually manufactured by solvent-free melt-spinning techniques.[1]

A scalable, solvent-free melt extrusion process was used to create bio-based polymer optical fibers (Bio-POFs) from glycerol triacetate-plasticized cellulose diacetate. Continuous processing methods were employed with cellulose diacetate contents of 60 wt-% and 70 wt-%. The resulting fibers were optically characterized using UV/Vis and near-infrared (NIR) spectroscopy to assess their spectral attenuation.[2]

A minimum attenuation of 31.8 dB m^{-1} at 950 nm was achieved, indicating a substantial improvement over previously reported cellulose-based optical fibers and narrowing the performance gap compared to non-renewable POFs. The fibers demonstrate stable optical transmission in both the visible and NIR regions, confirming the suitability for short-distance light-guiding applications.[2]

These results highlight that melt extrusion of plasticized cellulose diacetate is a viable manufacturing route for sustainable Bio-POFs, combining industrially relevant processing with competitive optical performance.

References

[1] M. Reimer, D. Van Opdenbosch, C. Zollfrank, *Biomacromolecules* **2021**, *22*, 3297.
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Fabrication of films based on pectin derived from apple pomace for packaging applications

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Pectin is an abundant biopolymer, derived from fruit processing residues, and a very promising biocompatible candidate for sustainable, degradable and water-soluble packaging. This study investigates the development of pectin-based films using industrial apple residues from the Saxony region (Germany). By systematically varying formulations and processing parameters, the work provides a detailed understanding of film development and presents a comprehensive overview of the resulting material. A sequential design of experiments (DoE) was applied to evaluate the combined effects of pectin and polyvinyl alcohol (PVA). Furthermore, citric acid (CA) was added as a crosslinker, as well as glycerol as a plasticizer. The DoE was used to (i) screen pure and blended systems, (ii) optimize key film properties, such as tensile strength, water vapor permeability (WVP), and water vapor transmission rate (WVTR), as well as to (iii) assess the reinforcing effect of the added fiber residues.

Comprehensive characterization, including FTIR, rheology, TGA, DSC, and SEM, provided insight into structure–property relationships. The results demonstrate that the targeted combination of pectin with PVA, CA, and biomass-derived fibers significantly enhances the films performance, such as higher tensile strength or lower WVTR. Overall, this work establishes a systematic framework for designing pectin-based materials and highlights the potential of converting regional agro-industrial residues into high-performance, sustainable packaging solutions, supporting circularity and resource efficiency.

One Polymer, Various Architectures: Thermoresponsive Methylcellulose Across Soft and Structured Materials

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Methylcellulose (MC) is a sustainable and thermoresponsive biopolymer capable of forming a remarkable variety of structures across multiple length scales. Depending on temperature, environment, and processing conditions, the same polymer system can transition from molecular assemblies in solution to complex nano- and microstructured materials.

By linking experimental results with selected examples from the literature, this work provides a broader perspective on MC as a versatile platform material for responsive and sustainable biomaterials. Particular emphasis is placed on how temperature-driven self-assembly, fibrillar structuring, and processing conditions influence material behavior across solutions, interfaces, films, and fibrous systems. For example, in emulsion systems, MC forms fibrillar structures in aqueous solution whose morphology and dynamics strongly affect interfacial interactions and emulsion stabilization mechanisms.

The presented work further demonstrates how these responsive characteristics can be transferred into solid-state systems such as transparent cast films and electrospun nanofiber networks. Even after crosslinking, MC-based materials can retain responsive behavior while gaining structural stability, demonstrating the potential of combining adaptability with functional material architectures.

By combining rheology, SAXS, microscopy, and spectroscopic methods, the relationship between molecular interactions, hierarchical structure formation, and resulting material properties is illustrated across different material states.

The findings underline the versatility of MC as a platform material for thermoresponsive architectures spanning soft matter, interfaces, and structured functional materials.

Impact of cellulose nanocrystal surface charge on the formation and stabilization of metal nanoparticles

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Nanocellulose is well recognized for its reducing and stabilizing properties in the green synthesis of metal nanoparticles, which allows for the development of multifunctional nanohybrid materials. Native hydroxyl and aldehyde groups on the nanocellulose surface exhibit reducing capabilities, while anionic functional groups - such as carboxyl or sulfate half esters introduced during their production - contribute significantly to nanoparticle stabilization. Consequently, the ratio between these reducing and stabilizing functional groups is likely to play a crucial role in the formation of metal nanoparticles.

This study investigates how varying the surface charge densities of TEMPO (2,2,6,6-Tetramethylpiperidinyloxyl) oxidized bacterial cellulose nanocrystals (CNC) with carboxyl group contents of 0.4, 0.7, and 0.9 mmol/g affect the *in-situ* synthesis and stabilization of gold nanoparticles (AuNP). The nanoparticle synthesis was carried out in aqueous solution using a microwave reactor, without the addition of further reducing agents.

AuNPs exhibit a distinct absorption peak in the UV-Vis spectrum, which provides initial insights into their size and morphology. [1] The results indicated that a lower carboxyl group content in the CNCs leads to a higher AuNP concentration and an increased particle size. The size of AuNPs was verified by high-resolution transmission electron microscopy (HRTEM) and X-ray diffraction (XRD). X-ray photoelectron spectroscopy (XPS) was used to monitor the reduction of the metal precursor salt to its elemental form.

Overall, our findings highlight the significant influence of the surface charge density of CNCs on the synthesis, structural properties, and stabilization of gold nanoparticles. Controlling these parameters is essential for tailoring the functionality of metal nano particles for applications, for example, in catalysis or sensing.

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Long-Term High-Throughput Microalgal Cell Culture at a Scale-Down Level

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In recent years, microalgae cultivation has seen significant development for the treatment of liquid industrial pollutants[1]. However, there is still a need to increase the number of trials to validate and improve the experimental analysis. Therefore, in order to achieve versatility of data in sample handling, reduced volume is required. These efforts are aimed at future industrial scalability. In this regard, this study presents a high-throughput (HTP) platform capable of operating with 200 µL for two weeks and successfully overcoming the challenge of desiccation. Under controlled conditions, this study compares cell growth from 96-well with 24-well microplate and 50 mL lab-scale volume i.e., rotation speed and artificial light. Appreciable differences in growth rate are shown regarding future perspectives. Furthermore, one major challenge is achieving compatible growth inside hydrogels for cell immobilisation and biosensors to monitor growth dynamics.

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Electrospinning of Nanocellulose-stabilized Gelatin/Dextran Water-in-Water Emulsions: Toward Structured and Stabilized Biopolymer Nanofibers

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Water-in-water (W/W) Pickering emulsions based on biopolymers offer a promising platform for fabricating structured, sustainable nanofibrous materials. Model systems such as polyethylene oxide (PEO)/dextran have been widely used to investigate phase behavior and emulsion formation. Building on this framework, we transfer the approach to gelatin (GEL)/dextran systems, where the introduction of a protein-based polymer enables additional intermolecular interactions and improved relevance for functional fibrous materials. The objective of this study is to investigate the electrospinning (ES) of GEL/dextran Pickering emulsions stabilized by cellulose nanocrystals (CNC), with a focus on emulsion stability, fiber morphology, and post-spinning stabilization. Systematic optimization has been initiated for GEL/dextran system at a 70:30 mass ratio, including adjustments to ES parameters to achieve continuous, defect-free fibers. Preliminary results indicate that stable emulsions can be obtained using CNC as a particle stabilizer, enabling the formation of electrospun fibers with tunable morphology. Confocal laser scanning microscopy is employed to visualize the phase distribution within the fibers and to distinguish between GEL and dextran domains, providing insights into core–shell or phase-separated structures. These observations are used to correlate emulsion properties with the resulting fiber architecture. To ensure structural integrity in aqueous environments, initial crosslinking of GEL-based fibers has been performed as a proof-of-concept, with ongoing efforts directed toward the development of non-toxic crosslinking strategies. Overall, this work translates insights from model W/W systems to GEL-based emulsions, enabling the development of stable and structured nanofibrous materials for potential biomedical applications.

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.

Natural Resins as Bio-based Binders for Lignocellulosic Composite Materials

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For wood-based fiber materials, the applied binder determines the product's lifespan and environmental impact, rather than the lignocellulosic fibers. Commonly applied adhesives of petrochemical origin hinder biodegradability. Additionally, they are a well-documented major source of formaldehyde emissions, especially as volatile organic compounds (VOCs). Given that, the use of more sustainable binders from renewable sources becomes crucial. To achieve this, it is required to develop binder systems with similar mechanical performance, moisture resistance, and additionally improved environmental compatibility.[1,2,3]

Selected natural waxes, resins, and gums, frequently grouped together under the term "natural resins", were evaluated as bio-based alternative binders for lignocellulosic fibrous wood composites. After characterization of chemical composition, solubility for application, and thermal behavior, binder-coated wood paper sheets were produced by solvent application and hot pressing. This was followed by tensile testing under standard conditions and after accelerated hygrothermal weathering. Moisture stability was assessed by water absorption measurements. Biodegradation was investigated under aerobic soil conditions via CO_2 evolution over 91 days.

All investigated binders increase the tensile strength and stiffness of the wood paper substrate. Polysaccharide-rich gums, particularly gum arabic and myrrh, provide the most pronounced mechanical reinforcement. In contrast, waxes and several resin-based binders exhibit the highest water repellency. Biodegradation behavior also varies markedly depending on binder chemistry. Hydrophilic gums show the highest degree of mineralization, whereas highly hydrophobic waxes and resins display only limited degradation. Overall, the results reveal a clear trade-off between mechanical reinforcement, moisture protection, and biodegradability. This indicates that natural binders should be selected according to specific application requirements rather than considered universal replacements for synthetic adhesive systems.

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Long-term stability of natural fiber insulation material: Establishing aging protocols and open research questions

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Insulation materials derived from renewable resources have attracted considerable interest as alternatives in construction applications, valued for their hygrothermal properties, carbon sequestration potential, and availability of sustainable raw materials. While the mechanical, thermal, and hygroscopic properties of natural fibers — including wood, hemp, straw, jute, sheep wool, etc. — are relatively well documented[1–3]. Their long-term durability under realistic service conditions remains a critical, largely unaddressed gap.

Using natural fibers for thermal insulation represents a promising path to lead the building industry towards a sustainable, energy-efficient future. However, their long-term performance under realistic environmental and service conditions is poorly understood. Standardized aging protocols for such systems do not yet exist.

This work investigates wood fiber composites bound with a biogenic binder, with the main focus on assessing their long-term stability and durability. To answer the research question regarding this aspect, a validation method is required to best predict the natural degradation of these natural fiber-based insulation materials, and to determine which mechanical and chemical properties are most sensitive to aging-induced changes. Climate chambers can be used to provide controlled humidity/temperature, and standards can be adapted to best compare the differences in degradation behavior between accelerated and natural aging. Subsequently, the durability of the insulation materials can be evaluated using mechanical testing methods, such as tensile and compression tests. ATR-FTIR spectroscopy can be used to analyze material composition.

Key open questions driving this research include: What can be done to bridge the gap between climate chamber-based weathering protocols and the natural degradation of bio-based insulation materials? Which aging parameters most significantly affect the integrity of these insulation materials? And what combination of standard adaptations and characterization methods can best capture the relevant degradation mechanisms for biogenic systems?

This contribution invites discussion with researchers working on durability testing, biobased composites, and the standardization of material aging to develop robust, transferable testing methodologies for next-generation sustainable insulation.

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Phase Separation and Directed Assembly of Chitin Nanocrystals into Liquid Crystalline Films

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Self-assembled chiral nematic films were prepared from the isolated anisotropic phase under an external magnetic field. Polarized optical microscopy (POM) confirmed the birefringent nature of the films, while cross-sectional scanning electron microscopy (SEM) further verified the presence of a Bouligand structure. In addition, highly oriented, macroscopically anisotropic nematic films were fabricated from the isotropic phase by applying shear forces. Using a design of experiments (DoE) approach, key processing parameters, including suspension concentration, pH, shear rate, drying temperature, and wet film thickness, were systematically optimized to obtain nematic films with a high degree of orientational order. Based on an improved birefringence/POM image analysis method, the maximum apparent order parameter, estimated from the dichroic ratio D, reached approximately 0.93. Furthermore, chiral nematic composite films doped with the photoresponsive molecule TEGABS were prepared, together with relatively disordered films obtained by rapid evaporation in the absence of external field alignment as reference samples. The nanomechanical properties of these four types of films were compared under identical environmental conditions using nanoindentation, including hardness and indentation modulus. For the TEGABS-doped composite films, UV–Vis spectroscopy was further employed to evaluate their photoresponsive behavior and reversible recovery capability.