XXXI Conference
Polish Chitin Society
Katowice
September, 23-25th, 2026

# NEW ASPECTS ON CHEMISTRY AND APPLICATION OF CHITIN AND ITS DERIVATIVES

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**XXXI Conference of Polish Chitin Society**

# *"NEW ASPECTS ON CHEMISTRY AND APPLICATION OF CHITIN AND ITS DERIVATIVES.*

## *Chitin, chitosan, and other polysaccharides"*

**Katowice, Poland**
**September 23rd-25th 2026**
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# CONFERENCE SCHEDULE

## September 23rd 2026 – Wednesday

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| **$17^{00}$-$19^{00}$** | **Registration** |
| **$19^{00}$-$20^{00}$** | **Dinner** |

## September 24th 2026 – Thursday

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| **$9^{30}$-$10^{10}$** | **OPENING CEREMONY**<br>**Katarzyna Struszczyk-Świta, Ph.D., President of PTChit** |
| | **Prof. Henryk Struszczyk prize - giving ceremony** |

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| **SESSION A<br>ORAL PRESENTATION** | | |
| **Chairman** | | **Radosław Wach, Ph.D., D.Sc.** |
| **A1** | **$10^{10}$-$10^{35}$** | **Weronika Gonciarz, Marek Brzeziński, Magdalena Chmiela**<br>**UPREGULATION OF INNATE AND ADAPTIVE IMMUNE MECHANISMS FACILITATING PREVENTION OF GASTRIC *HELICOBACTER PYLORI* INFECTION IN GUINEA PIGS BY *PER OS* ADMINISTRATION OF CHITOSAN MICROPARTICLES LOADED WITH *MYCOBACTERIUM BOVIS* BCG** |
| **A2** | **$10^{35}$-$11^{00}$** | **Katarzyna Kresse-Walczak, Heike Meissner, Bruna Neves de Freitas, Klaus Boening**<br>**FROM ARTIFICIAL BIOFILM TO ARTIFICIAL CALCULUS: BIOPOLYMER-BASED EQUIVALENTS FOR RESEARCH AND EDUCATION** |
| **A3** | **$11^{00}$-$11^{25}$** | **Olga Marchut-Mikołajczyk**<br>**CHITOSAN-BASED SOLUTIONS FOR ENVIRONMENTAL REMEDIATION** |
| **A4** | **$11^{25}$-$11^{50}$** | **Eugeniusz Świstuń, Tomasz Bajda, Julia Czerska**<br>**FROM FOREST PESTS TO BIOPOLYMERS: CHITIN OBTAINED FROM INSECTS COLLECTED DURING FOREST PROTECTION OPERATIONS** |
| **A5** | **$11^{50}$-$12^{15}$** | **Noira Vokhidova, Musurmon Yusupov**<br>**DEVELOPMENT AND EVALUATION OF CHITOSAN-BASED SORBENTS FOR ENVIRONMENTAL POLLUTANT ELIMINATION: SYNTHESIS AND SORPTION PERFORMANCE** |
| **$12^{15}$-$12^{30}$** | | **Coffee/tea break** |

| $12^{30}$-$13^{30}$ | **SESSION B**<br>**POSTER PRESENTATION** |
|---|---|
| **B1** | **Monika Sikora, Maria Wiśniewska-Wrona, Iwona Kucińska-Król, Joanna Olczyk, Anetta Walawska, Marcin Kudzin**<br>**HYDROMULCH BASED ON NATURAL POLYMERS** |
| **B2** | **Maria Wiśniewska-Wrona, Monika Sikora, Iwona Kucińska-Król, Joanna Olczyk, Magdalena Olak-Kucharczyk**<br>**REMOVAL OF PETROLEUM-DERIVED CONTAMINANTS FROM SOIL AND GROUNDWATER THROUGH IN SITU ECOHYDROLOGICAL OZONATION USING NATURAL POLYMERS** |
| **B3** | **Piotr Drożdżyński**<br>**CHITOSAN-BIOSURFACTANT HYBRID SYSTEMS: FROM PHYSICOCHEMICAL INTERACTIONS TO FUNCTIONAL BIOFORMULATIONS** |
| **B4** | **Urszula Filipkowska, Tomasz Jóźwiak**<br>**OZONATION AS AN EFFECTIVE METHOD FOR DECOLORIZATION OF AQUEOUS DYE SOLUTIONS** |
| **B5** | **Małgorzata Gnus**<br>**CHITOSAN MODIFIED WITH EPICHLOROHYDRIN AS AN ADDITION TO EPOXY RESIN** |
| **B6** | **Agata Niemczyk, Daniel Deacu, Jolanta Baranowska**<br>**POLYSACCHARIDE THIN FILMS OBTAINED BY PULSED ELECTRON DEPOSITION** |
| **B7** | **Barbara Hawrylak-Nowak, Maria Stasińska-Jakubas, Agata Majewska-Fala**<br>**EFFECTS OF CHITOSAN ON PHYSIOLOGICAL RESPONSES AND HIGH-TEMPERATURE STRESS TOLERANCE IN COMMON WHEAT (*TRITICUM AESTIVIUM* L.)** |
| **B8** | **Dominik Müller, Alicja Matyjewicz, Beata Paczosa-Bator, Magdalena Luty-Błocho, Bożena Muszyńska, Agata Krakowska**<br>**CHITOSAN EXTRACTED FROM *IN VITRO* MUSHROOM CULTURES OF *PLEUROTUS OSTREATUS* ENRICHED WITH GOLD NANOPARTICLES AS A NOVEL ANTIMICROBIAL AGENT IN WOUND HEALING** |
| **B9** | **Łukasz Wujcicki, Joanna Kluczka, Jakub Adamek , Klaudiusz Gołombek**<br>**ORGANIC ACID-FUNCTIONALIZED CHITOSAN FOR THE RECOVERY OF CRITICAL METALS FROM BATTERY WASTEWATER** |
| **B10** | **Karolina Czajkowska, Maciej Rybicki, Karol K. Kłosiński, Radosław A. Wach**<br>**PREDICTING THE ANTIMICROBIAL EFFICACY OF CHITOSAN: A MULTIPLE REGRESSION ANALYSIS OF MOLECULAR WEIGHT AND DEGREE OF DEACETYLATIOM** |
| **B11** | **Alicja Matyjewicz, Dominik Müller, Beata Paczosa-Bator, Tomasz Skalski, Bożena Muszyńska, Agata Krakowska**<br>**FUNGAL CHITOSAN AND Γ-POLYGLUTAMIC ACID BIOCOMPOSITE FOR WOUND DRESSING APPLICATIONS** |

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| **B12** | **Aneta Ostróżka-Cieślik**<br>**RESEARCH INTO HYBRID CHITOSAN HYDROGELS CONTAINING INSULIN IN THE CONTEXT OF POTENTIAL APPLICATIONS IN THE TREATMENT OF CHRONIC WOUNDS** |
| **B13** | **Katarzyna Struszczyk-Świta**<br>**MICROWAVE-ASSISTED EXTRACTION OF CHITOSAN FROM FILAMENTOUS FUNGAL BIOMASS** |
| **B14** | **Aji Suhartoyo, Miloslav Machacek, Hana Jansova, Magdalena Wujak, Kinga Mylkie, Aleksander Smolarkiewicz-Wyczachowski, Marta Ziegler-Borowska, Dorota Chełminiak-Dudkiewicz**<br>**ZINC PHTHALOCYANINE-FUNCTIONALIZED CHITOSAN BIOMATERIAL FOR POTENTIAL WOUND-HEALING APPLICATIONS** |

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| **$13^{30}$-$14^{30}$** | **Lunch** |
| **$14^{30}$-$19^{00}$** | **Visiting the landmarks of Katowice with a guide.**<br>***Katowice: From Industrial Heritage to a Modern City*** |
| **$20^{00}$-$23^{00}$** | **Gala Dinner: *A Taste of Silesian Hospitality*** |

## September 25th 2026 – Friday

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| **$9^{00}$-$10^{30}$** | | **General Assembly of the Polish Chitin Society**<br>*(only for PTChit members)* |
| | | **SESSION C**<br>**ORAL PRESENTATION** |
| **Chairman** | | **Katarzyna Kresse-Walczak, PD Dr. med. dent.** |
| **C1** | **$10^{30}$-$10^{55}$** | **Magdalena Gierszewska, Ewa Olewnik-Kruszkowska**<br>**THE ROLE OF DEEP EUTECTIC SOLVENT COMPOSITION IN TAILORING THE PROPERTIES OF CHITOSAN-BASED PACKAGING** |
| **C2** | **$10^{55}$-$11^{20}$** | **Tomasz Mańdok, Joanna Kluczka, Klaudiusz Gołombek, Jakub Adamek**<br>**SEPARATION OF GALLIUM FROM ALUMINIUM IONS USING ION-IMPRINTED CROSS-LINKED CHITOSAN SORBENT** |
| **C3** | **$11^{20}$-$11^{45}$** | **Joanna Odrobińska-Baliś, Adriana Gilarska, Dorota Lachowicz, Krzysztof Szczepanowicz, Adelajda Adamczyk, Agnieszka Kłapcia, Agnieszka Radziszewska, Lilianna Szyk-Warszyńska, Dawid Lupa**<br>**CHITOSAN HYDROGEL-POLYMERIC CAPSULE SYSTEM FOR EQUINE DISTAL LIMB WOUND MANAGEMENT** |
| **C4** | **$11^{45}$-$12^{10}$** | **Daniel Deacu, Paweł Figiel, Paweł Kochmański, Sebastian Fryska, Jolanta Baranowska, Dariusz Moszyński, Agata Goszczyńska, Tomasz Idzik, Jacek Sośnicki, Agata Niemczyk**<br>**PULSED ELECTRON DEPOSITION OF GLUCOSE THIN FILMS: THE FIRST STEP TOWARD SOLVENT-FREE DEPOSITION OF POLYSACCHARIDES** |

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| **$12^{10}$-$12^{30}$** | | **Coffee/tea break** |
| **C5** | **$12^{30}$-$12^{55}$** | **Kamila Rułka-Olszak, Anna Masek**<br>**FUNCTIONALIZATION OF CHITOSAN WITH POLYPHENOLIC COMPOUNDS TO OBTAIN BIODEGRADABLE MATERIALS WITH ANTIOXIDANT PROPERTIES** |
| **C6** | **$12^{55}$-$13^{20}$** | **Aji Suhartoyo, Dorota Chełminiak-Dudkiewicz, Miloslav Machacek, Hana Jansova, Klara Konecna, Ondrej Jandourek, Puji Astuti, Sebastian Druzynski, Kinga Mylkie, Marta Ziegler-Borowska**<br>**NON-CROSSLINKED GELLAN GUM-BASED SPONGE REINFORCED WITH MUSA SAPIENTUM AND FUNCTIONALIZED WITH CUCURBITA MAXIMA EXTRACT FOR ANTIOXIDANT AND ANTIBACTERIAL WOUND DRESSING** |
| **$13^{20}$-$13^{40}$** | | **Coffee/tea break** |

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| **$13^{40}$-$14^{00}$** | **Closing of the conference** |
| **$14^{00}$-$15^{00}$** | **Lunch** |

**Łukasz Wujcicki**
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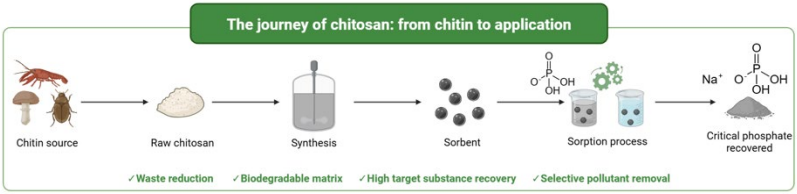
## FROM WASTE TO VALUE: CHITOSAN-BASED SORBENTS FOR THE REMOVAL OF CRITICAL RAW MATERIALS FROM WATER

Sustainable sorption technologies are increasingly needed for water and wastewater treatment. Recent hydrological extremes in Europe highlight the need to protect water ecosystems and manage water quality. Poland has relatively low water resources, with average water availability estimated at approximately 1,600 $m^3$ per capita per year, compared with the European average of 4,500 $m^3$. Sorption using specially engineered materials has gained attention for its ability to remove pollutants and recover valuable components, including critical raw materials such as phosphates and strategic metal ions [1,2].

Current research on these approaches focuses on naturally occurring, readily available, eco-friendly materials. Chitosan has attracted particular interest because of its ease of modification, pH-dependent solubility, and its application in different forms, including hydrogels, nanofibres, and foams [2]. However, unmodified chitosan has limited pollutant-removal capability and requires further modification. In this work, we incorporated nickel(II) and cerium(IV) ions into chitosan, followed by coagulation in a sodium hydroxide solution. This process directly yields sorbents with high phosphate uptake, with maximum sorption capacities of 62.5 mg/g and 71.6 mg/g, respectively [3–5].

These materials were characterized using FTIR spectroscopy, XRD, scanning electron microscopy with EDS analysis (SEM-EDS), and XPS. Sorbents modified with nickel and cerium ions offer a direct solution for preventing eutrophication and reducing water quality degradation caused by phosphate contamination. Persistent excessive phosphate concentrations in Polish coastal waters have contributed to annual cyanobacterial blooms. The studies demonstrate the potential of metal-modified chitosan as a multifunctional, biodegradable platform for removal and recovery of phosphates.



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# *Session A*

**Weronika Gonciarz**[1], **Marek Brzeziński**[2], **Magdalena Chmiela**[1]

[1] – *University of Lodz, Department of Immunology and Infectious Biology, Banacha 12/14, Poland*

[2] – *Polish Academy of Sciences, Centre of Molecular and Macromolecular Studies, Sienkiewicza 112, Poland*

## UPREGULATION OF INNATE AND ADAPTIVE IMMUNE MECHANISMS FACILITATING PREVENTION OF GASTRIC *HELICOBACTER PYLORI* INFECTION IN GUINEA PIGS BY *PER OS* ADMINISTRATION OF CHITOSAN MICROPARTICLES LOADED WITH *MYCOBACTERIUM BOVIS* BCG

*Helicobacter pylori* rods frequently colonize and damage the gastric mucosa in humans, causing inflammation, gastric or duodenal ulcers and even gastric cancer. *H. pylori* negatively modulates the activity of immune cells, including macrophages and lymphocytes facilitating the persistence of infection. Increasing resistance of *H. pylori* isolates to commonly used antibiotics diminishes the success of therapy. These prompt searches for new therapeutic formulations to improve the effectiveness of immune mechanisms against *H. pylori.* Based on the previous *in vitro* studies indicating the immunomodulatory properties of *Mycobacterium bovis* BCG vaccine bacilli, we developed chitosan microparticles-(CHI MPs) modified with N-acetylglucosamine-(G) or with Pluronic F-127-(P) to facilitate the delivery and persistence of live *M. bovis* BCG in the stomach and in the gut of *Cavia porcellus* susceptible to *H. pylori* infection. Methods: Animals (5/per group) were inoculated *per os* only with CHI MPs, G or P variant or both, or with such CHI MPs and then with the reference *H. pylori* CCUG17874 positive for cytotoxin-associated gene A-(cagA) (3 times in two-day intervals). Control animals received only *H. pylori* (positive control) or Brucella broth (negative control). Two assessment points have been selected: 7 and 28 days after the last *H. pylori* inoculation, mimicking early and chronic infection, respectively. Results: In the guinea pigs receiving G/P CHI MPs loaded with *M. bovis* BCG before inoculation with *H. pylori* we detected an increased number of myeloid precursors in the bone marrow and enhanced macrophage infiltration in the gastric tissue. The bone marrow-derived macrophages from this group showed enhanced phagocytic activity, whereas in animals inoculated only with *H. pylori,* this activity was negatively modulated. The protective effect of the studied CHI MPs was also associated with increased gastric concentrations of secretory IgA and enhanced splenocyte proliferation. Conclusions: The obtained results indicate the immunomodulatory potential of CHI MPs loaded with *M. bovis* BCG to improve innate and adaptive immune mechanisms, facilitating control of *H. pylori* infection in the guinea pig model.

*Acknowledgements:*
*The research was financially supported by the National Science Center with the grant SONATA 18 "Assessment of the ability of Mycobacterium bovis BCG-onco bacilli to control the development of Helicobacter pylori infection," UMO-2022/47/D/NZ7/01097.*

**Katarzyna Kresse-Walczak[1 2], Heike Meissner[2], Bruna Neves de Freitas[2], Klaus Boening[2]**

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## FROM ARTIFICIAL BIOFILM TO ARTIFICIAL CALCULUS: BIOPOLYMER-BASED EQUIVALENTS FOR RESEARCH AND EDUCATION

**Background:**
Chitosan is a biocompatible, non-toxic and biodegradable polymer with film-forming and adhesive properties. These properties make it a candidate material for artificial oral biofilm equivalents used in research and education. Conventional biofilm-simulating materials often differ from natural biofilm in adhesion, water resistance or mechanical behaviour, while microbial models are more complex and less suitable for standardised mechanical cleaning tests.

**Objective:**
To summarise the development of chitosan-based models for non-mineralised and mineralised oral biofilms and to assess their suitability for research and education.

**Materials and Methods:**
Artificial biofilm equivalents were prepared from chitosan and methylcellulose and applied to polymethylmethacrylate specimens or training teeth [1,2]. Their resistance to brushing was adjusted by changing the chitosan-to-methylcellulose ratio. The artificial biofilm equivalents were subjected to brushing in a brushing simulator and evaluated using digital photography and computer-assisted planimetry. Selected formulations were compared with natural denture biofilm [1]. The material concept was later extended to artificial calculus by adding tricalcium phosphate and testing removal by scaler instrumentation.

**Results:**
Increasing the methylcellulose content reduced abrasion resistance, while higher chitosan contents produced more resistant artificial biofilm equivalents [2]. Selected formulations showed brushing behaviour similar to natural denture biofilm, and the preparation and testing procedures were feasible and reproducible [1]. The artificial biofilm equivalent could also be applied to and mechanically removed from training teeth. The addition of tricalcium phosphate enabled the development of artificial calculus with adjustable resistance to instrumentation.

**Conclusions:**
Chitosan-based artificial oral biofilm eqiuvalents can be adapted for different mechanical cleaning tasks by modifying their composition. These non-microbial artificial equivalents are suitable for studying mechanical removal by brushing or

instrumentation and for practical teaching, but they are not intended to replace microbial models for biological or antimicrobial outcomes. Current work investigates colour calibration of three-dimensional scanner data as a basis for automated quantification of residual artificial biofilm equivalents.

*Acknowledgements:*
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References:

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## CHITOSAN-BASED SOLUTIONS FOR ENVIRONMENTAL REMEDIATION

The growing presence of heavy metals, pharmaceuticals, dyes, nutrients, and other emerging contaminants in water has increased the demand for effective and sustainable remediation technologies. Among natural biopolymers, chitosan has gained particular attention because of its biodegradability, low toxicity, and the ease with which its structure can be modified for different environmental applications.

Studies published between 2015 and 2025 show that chemical modification of chitosan has considerably broadened its application in water and wastewater treatment. Native, crosslinked, grafted, magnetic, composite, and nanostructured chitosan-based materials have been successfully used for the removal of both inorganic and organic pollutants. Their performance is closely related to the type of modification and the dominant removal mechanisms, including electrostatic attraction, complexation, ion exchange, hydrogen bonding, and π–π interactions.

Recent studies have also demonstrated the potential of combining chitosan with biological systems. Materials incorporating microorganisms, microalgae, or biofilm-based technologies can couple adsorption with biodegradation, improving treatment efficiency, biomass retention, and process stability. At the same time, increasing attention is being paid to adsorbent regeneration, material reusability, and life-cycle aspects, which are essential for the practical implementation of these materials.

Despite the significant progress made in recent years, several challenges still limit the wider application of chitosan-based materials. These include reduced performance in complex wastewater, limited long-term stability, regeneration efficiency, and the need for scalable production methods. Future research should focus on multifunctional materials and hybrid treatment systems that combine adsorption with biological processes to support more sustainable environmental remediation and circular economy strategies.

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siderophores-producing bacteria immobilized in chitosan beads. Biodegradation 32, 697–710. DOI: 10.1007/s10532-021-09961-y.

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## FROM FOREST PESTS TO BIOPOLYMERS: CHITIN OBTAINED FROM INSECTS COLLECTED DURING FOREST PROTECTION OPERATIONS

Chitosan, a biopolymer produced through the deacetylation of chitin, has attracted considerable attention owing to its biodegradability, biocompatibility, and antimicrobial activity, enabling applications in biomedicine, agriculture, and environmental technologies [1]. Industrial chitosan production is currently dominated by marine crustaceans; however, these sources require intensive demineralization because of their high mineral content and are associated with environmental and economic limitations related to transport and processing [2]. In contrast, insect exoskeletons contain substantially lower amounts of inorganic compounds, allowing milder extraction conditions and offering a potentially more sustainable terrestrial alternative [3].

Here, we investigate the feasibility of producing chitosan from forest pest insects, particularly bark beetles collected during sanitary forest protection activities. Although generated in large quantities during outbreak events, this biomass remains largely underutilized [4]. Chitin and chitosan were obtained through sequential deproteinization, demineralization, deacetylation, and decolorization steps. The extraction yield of chitin from bark beetles reached 17.03%, exceeding values commonly reported for several commercially farmed insect species. The obtained materials were characterized using Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), scanning electron microscopy (SEM), and simultaneous thermal analysis (STA). XRD analysis confirmed the predominance of the a-chitin polymorph, characteristic of structurally ordered insect-derived chitin [5].

The synthesized chitosan exhibited physicochemical properties comparable to commercial materials, including high deacetylation and favorable thermal stability.

Overall, this work establishes forest pest biomass as a viable and sustainable source of chitin and chitosan, linking forest protection practices with value-added biomaterial production and supporting the development of circular bioeconomy strategies.

*Acknowledgements:*
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## DEVELOPMENT AND EVALUATION OF CHITOSAN-BASED SORBENTS FOR ENVIRONMENTAL POLLUTANT ELIMINATION: SYNTHESIS AND SORPTION PERFORMANCE

Layered double hydroxides (LDHs), also referred to as hydrotalcites, are two-dimensional inorganic materials characterized by their layered structure [1-3]. Their empirical chemical formula is typically represented as follows: $[M^{2+}_{1-x} M^{3+} \times (OH)_2]^{x+} [A^{n-}] \times mH_2O$

Typically, the $M^{2+}$ ions in their structure have ionic radii ranging from 0.65 to 0.80 Å and include ions such as $Zn^{2+}$, $Ca^{2+}$, $Mn^{2+}$, $Mg^{2+}$, $Ni^{2+}$, and $Fe^{2+}$. The trivalent metal ions, $M^{3+}$, have ionic radii between 0.62 and 0.69 Å and include ions such as $Fe^{3+}$, $Al^{3+}$. The anions ($A^{n-}$) are located in the interlayer spaces of the layered structure, compensating for the positive charge of the metal layers. Thanks to their unique layered structure, anion exchange capacity, and thermal stability, LDHs with various compositions have been synthesized. These materials find applications in catalysis, pharmaceuticals, electrochemistry, and as sorbents for the treatmentof industrial wastewater.

The rational use of water resources, their protection from pollution by household and industrial waste, and the proper organization of water purification processes are urgent tasks. The development of sorbents based on chitosan (CS) composites with layered double hydroxides (LDHs) offers new opportunities for their application in the treatment of industrial wastewater. In this study, composites of *Bombyx mori CS* with layered double hydroxides-specifically $Mg^{2+}/Fe^{3+}$ - were synthesized using a combination of coprecipitation and sonochemical techniques.

According to scanning electron microscopy micrographs, the obtained composites based on layered double hydroxides exhibit morphologies similar to hydrotalcites, characterized by interlayer regions containing water molecules and macro-molecules of organic pollutants. Additionally, X-ray diffraction patterns indicate the presence of characteristic peaks at 2θ values of 12.23° (003), 22.84° (006), 34.41° (009), 38.98° (015), and 60.1° (110), which are in good agreement with literature data [4-7].

A method for synthesizing layered double hydroxides (LDHs) and their composites has been developed. The sorption properties, morphological features, and structural characteristics of CS/LDH composites were systematically studied. To evaluate the sorption capacity of the composites in model systems, the BET method was employed based on nitrogen adsorption isotherms to determine surface area, while the BJH model was used to analyze pore size distribution and

adsorption/desorption isotherms. The results demonstrated significant enhancement in surface area, with values ranging from 20.52 $m^2/g$ to 99.84 $m^2/g$ under optimal conditions - approximately a fivefold increase compared to initial samples.These findings indicate that the synthesized $Mg^{2+}/Fe^{3+}$:CS nanocomposite is a promising, cost-effective, and stable material for the removal of heavy metal ions and dyes from industrial wastewater.

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# *Session B*

# B1

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## HYDROMULCH BASED ON NATURAL POLYMERS

The development of new materials based on natural polymers obtained through recycling processes offers a circular economy-friendly alternative to the use and management of large quantities of plant-based waste. Biopolymers such as alginate, chitosan, and CMC (carboxymethylcellulose) have a highly positive impact on the terrestrial ecosystem, providing an ecological alternative to synthetic plastics. Used in agriculture in the form of beads (capsules) and hydromulch films, they are completely biodegradable, improve soil structure, stimulate plant growth, and protect soil microorganisms. Both films and hydromulch balls gradually disintegrate under the influence of moisture and microorganisms, which influences soil parameters, including increased water retention, improved aggregate structure, and temperature regulation. Unlike plastic (which degrades into toxic microplastics), biopolymers benefit living organisms through natural protection against soil pathogens, safe biodegradation, and a beneficial effect on plant growth.

Because these biopolymers have the ability to absorb and store water, they can maintain optimal humidity around seeds, significantly accelerating and uniforming the seed germination process. A key aspect of their use in hydromulch as a binder is that they are non-toxic, safe for the ecosystem, and naturally decompose, enriching the soil with organic matter.

To address the social and economic challenges associated with the accumulation of large amounts of biowaste, a new composite biomaterial based on natural polymers has been proposed. It serves as a binder/adhesive in hydromulch for the waste fibrous cellulose fraction (recycled), prepared from natural polymers: carboxymethylcellulose (CMC), alginate (Alg), and chitosan (Chit). The natural polymers and their compositions proposed in this study act as an ecological binder in hydromulch. Their primary function is to create a viscous matrix that binds textile waste, seeds, and fertilizers into a uniform, permeable structure, thus protecting the soil from water and wind erosion, creating optimal conditions for plant germination, and facilitating vegetation. Based on plate tests, the effect of solutions of Alg, Chit/CMC and the Alg, Chit/CMC composition with added fiber fraction, which act as a binder/binder in hydromulch, on the germination capacity of radish seeds was assessed. Depending on the concentration, the preparations demonstrated a particularly strong stimulating effect on radish seed germination, increasing green mass or sprout length.

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# B2

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## REMOVAL OF PETROLEUM-DERIVED CONTAMINANTS FROM SOIL AND GROUNDWATER THROUGH IN SITU ECOHYDROLOGICAL OZONATION USING NATURAL POLYMERS

Contamination of groundwater and soil with substances generated during the processing, distribution, and transportation of crude oil and its derivatives poses the greatest threat to the environment and is among the most widespread forms of soil contamination. The extent of soil contamination with petroleum-derived compounds is largely determined by the soil's physical condition—particularly its structure and moisture content—as well as the extent of contamination at the site and the depth to which petroleum products penetrate.

Among the various components of the biosphere, soils occupy a special position, as they are not only the primary site of accumulation for many chemical pollutants but also serve as a protective filter, both for substances migrating into water—including highly volatile elements—and for the plants growing on them.

Petroleum products, which commonly pollute the environment, pose an increasingly serious ecological problem, as their contamination of water and soil not only adversely affects crop production but also poses a danger to human and animal health, given that most of them are toxic to living organisms. Therefore, the issue of neutralizing this type of contamination, as well as the remediation of land contaminated with petroleum-derived substances, appears to be of great importance.

Efforts should therefore be made to mitigate the effects of high concentrations of petroleum-derived substances in soil and groundwater by seeking new methods that, on the one hand, effectively limit the migration of these compounds in the soil and aquatic environments, and, on the other hand, reduce their negative environmental impacts.

In cases of minor contamination of soil and groundwater with petroleum-derived substances, the use of an integrated in-situ ozonation method employing natural polymers yields good results. The removal of petroleum-derived compounds from soil and groundwater using natural polymers such as cellulose, starch, chitosan, or natural humic acids) relies primarily on their sorption and the stimulation of biological processes (bioremediation). Natural biopolymers and humic-mineral preparations demonstrate a high capacity for effectively binding (sorption) organic ecotoxicants, including crude oil and petroleum products. This prevents their further migration within the soil profile and their infiltration into

groundwater. Additionally, naturally derived polymers improve the soil's crumb structure and air-water ratios, and provide an excellent environment for the growth of beneficial soil microorganisms (bacteria and fungi), which catalyze the breakdown of hydrocarbons into harmless products such as water and carbon dioxide.

Unlike synthetic polymers, natural substances, once they have fulfilled their function, undergo complete biodegradation within the ecosystem, without burdening it with persistent waste.

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# B3

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## CHITOSAN-BIOSURFACTANT HYBRID SYSTEMS: FROM PHYSICOCHEMICAL INTERACTIONS TO FUNCTIONAL BIOFORMULATIONS

Chitosan–biosurfactant (CS-BS) systems represent a promising class of multifunctional bio-based formulations combining the cationic, film-forming and bioactive properties of chitosan with the amphiphilic and interfacial activity of biosurfactants [1]. Despite the growing interest in these systems, the physicochemical basis of their interactions and the mechanisms underlying their potential synergistic effects remain insufficiently understood. Available studies indicate that CS-BS interactions may involve electrostatic attraction, hydrophobic association, self-assembly and the formation of complex colloidal structures. Depending on formulation conditions, these interactions can be exploited to produce nanoparticles, core–shell structures, coacervates and other organized delivery systems. The properties and performance of CS-BS formulations are strongly influenced by chitosan molecular weight and degree of deacetylation, pH, ionic strength, biosurfactant structure and concentration, as well as the resulting colloidal organization [2]. Experimental studies have demonstrated enhanced antimicrobial and antibiofilm activity, improved interfacial and colloidal properties, controlled delivery of bioactive compounds, and potential applications in plant protection, postharvest preservation and environmental remediation [3]. The available evidence suggests that the observed synergy is unlikely to result from a single, well-defined molecular mechanism but may instead emerge from the coupling of polymer–surfactant interactions, interfacial activity and multiscale system organization. However, direct experimental evidence linking molecular interactions with the functional performance of integrated CS-BS systems remains limited. Further studies combining advanced physicochemical characterization with biological and functional assays are therefore required to establish structure-property-activity relationships and support the rational design of effective CS-BS formulations.

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# B4

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## OZONATION AS AN EFFECTIVE METHOD FOR DECOLORIZATION OF AQUEOUS DYE SOLUTIONS

The aim of this study was to evaluate the effectiveness of ozonation in the removal of selected azo dyes from aqueous solutions: Reactive Black 5 (RB-5), Acid Red 18 (AR-18) and Direct Black 22 (DB-22). The experiments were carried out for dye concentrations of 50, 100 and 500 mg/dm³ at pH 7. The ozonation process was conducted from f1 to 10 minutes, and the degree of decolourisation was determined spectrophotometrically. In addition, the influence of ozonation on the degradation of organic compounds was assessed by measuring total organic carbon (TOC).

The results showed that ozonation was a highly effective method for dye decolourisation. After 10 minutes of treatment, the colour removal efficiency exceeded 99% in most cases. The highest efficiency was observed for Direct Black 22, while the lowest decolourisation efficiency, equal to 96.96%, was obtained for Acid Red 18 at the initial concentration of 500 mg/dm³. The TOC analysis confirmed that ozonation also contributed to the reduction of organic carbon content in the treated solutions, although the mineralisation efficiency depended on the type and initial concentration of the dye. After 10 minutes of ozonation, TOC removal ranged from 44% to 94%. The highest TOC reduction was obtained for Direct Black 22, reaching 85%, 91% and 94% for initial dye concentrations of 50, 100 and 500 mg/dm³, respectively. Lower TOC removal was observed for Reactive Black 5 and Acid Red 18, which indicates that decolourisation occurred faster than complete mineralisation of organic compounds.

The study demonstrated that ozonation is an effective process for the decolourisation and partial degradation of dye-containing aqueous solutions. However, due to incomplete mineralisation, especially for RB-5 and AR-18, ozonation may be particularly useful as a preliminary treatment step before subsequent processes such as sorption, coagulation or biological treatment.

# B5

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## CHITOSAN MODIFIED WITH EPICHLOROHYDRIN AS AN ADDITION TO EPOXY RESIN

Epoxy resins are commonly used in protective and industrial paints due to their excellent adhesion to the substrate, high mechanical resistance, and effective protection against chemicals and corrosion. Epoxy coatings are used on steel structures, industrial floors, tanks, and infrastructure components exposed to harsh operating conditions, among other applications.

The addition of epoxidized chitosan to epoxy resins used in paints can improve the protective and functional properties of the resulting coatings [1-3]. The presence of epoxy groups and chitosan's natural polysaccharide structure allow for better incorporation of the additive into the cross-linked resin network, which promotes increased adhesion of the coating to the substrate and improved sealing. Epoxidized chitosan can also limit the penetration of water, oxygen, and corrosive ions through the coating, increasing the paint's corrosion resistance. Furthermore, the presence of amine and hydroxyl groups can improve compatibility with pigments and fillers, as well as increase the coating's mechanical strength. Another significant advantage is the partial replacement of petrochemical raw materials with a naturally derived biopolymer, which aligns with the trend towards more sustainable and environmentally friendly coating materials.

The aim of this work was to obtain chitosan modified with epichlorohydrin and check its potential use as an additive to a varnish product based on epoxy resin. The effect of the modified chitosan addition on selected properties of the obtained epoxy coatings was determined.

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# B6

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## POLYSACCHARIDE THIN FILMS OBTAINED BY PULSED ELECTRON DEPOSITION

Polysaccharides are attractive coating materials owing to their renewable origin and chemical functionality. Their processing into thin films is, however, often limited by poor solubility and the absence of a stable melt. This is particularly relevant for chitin, while conventional processing of chitosan requires acidic media. Standard coating methods therefore depend on polymer dissolution or chemical modification, increasing process complexity and limiting the selection of substrates.

Physical vapour deposition offers a direct route from a solid polymer target to a coating. Pulsed electron deposition (PED) uses short, high-energy electron pulses to ablate the target material. The released species are transported through a low-pressure plasma and deposited onto a substrate. In contrast to conventional wet-processing methods, PED does not require polymer dissolution and enables direct processing of solid, unmodified target materials [1].

In this study, chitin and chitosan were used to obtain the for thin, continuous coatings by the PED method. The deposited films exhibited distinct surface characteristics, indicating that the chemical structure of the starting polysaccharide influences its behaviour during electron-beam ablation, transport and subsequent film growth. Differences suggest a material-dependent response to the PED process rather than a universal deposition behaviour for polysaccharides.

These results demonstrate the potential of PED as a solvent-free physical route for the deposition of polysaccharide thin films. The ability to process chitin and chitosan directly from solid targets opens a new approach to the fabrication of functional polysaccharide coatings.

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# B7

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## EFFECTS OF CHITOSAN ON PHYSIOLOGICAL RESPONSES AND HIGH-TEMPERATURE STRESS TOLERANCE IN COMMON WHEAT (*TRITICUM AESTIVUM* L.)

In an era of rapidly changing climatic conditions, the effects of high temperatures on cereal crops have become a major determinant of global food security. Excessively high temperatures can impair plant functioning and, consequently, threaten agricultural productivity.

This study focused on changes in the physiological and biochemical parameters determining the tolerance of common wheat (*Triticum aestivum* L.) to high-temperature stress and on the potential protective role of chitosan. Measurements were performed at two time points separated by six days to evaluate the effects of short- and long-term stress on selected photosynthetic parameters (chlorophyll *a* fluorescence and chlorophyll and carotenoid contents), oxidative stress indicators (reactive oxygen species accumulation and membrane lipid peroxidation), and stress-induced metabolites (free proline content).

High-temperature stress negatively affected both fresh and dry plant biomass. Moreover, high-temperature stress reduced chlorophyll *a* content and significantly decreased both the minimum and maximum chlorophyll *a* fluorescence. The stress treatment also approximately doubled the level of membrane lipid peroxidation. Chitosan application under optimal temperature conditions stimulated leaf elongation; however, this effect disappeared under stress conditions. In contrast, foliar application of chitosan under high-temperature stress exerted a beneficial effect by reducing the accumulation of reactive oxygen species and free proline.

The obtained results indicate that the primary mechanism underlying the protective effect of chitosan under high-temperature stress involves limiting reactive oxygen species accumulation and modulating proline metabolism, whereas its effects on plant growth and photosynthetic performance were limited.

# B8

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## CHITOSAN EXTRACTED FROM *IN VITRO* MUSHROOM CULTURES OF *PLEUROTUS OSTREATUS* ENRICHED WITH GOLD NANOPARTICLES AS A NOVEL ANTIMICROBIAL AGENT IN WOUND HEALING

*Pleurotus ostreatus*, commonly referred to as oyster mushroom, is a species of edible mushroom found in temperate to subtropical climate in forests around the world. It's biomass is rich in β-glucans, antioxidants, phenolic compounds and polysaccharides such as chitin [1]. Although chitin constitutes approximately 3–5% of the dry biomass, *P. ostreatus* presents a promising alternative source of fungal chitosan due to its rapid growth, ease of cultivation, and the possibility of producing biomass under controlled *in vitro* conditions [2].

While silver nanoparticles (AgNPs) are widely recognized for their strong antimicrobial activity, concerns regarding their toxicity and potential health risks have have lead the European Union to classify them as potentially toxic and restrict their use in cosmetics [3]. Consequently, gold nanoparticles (AuNPs) have gained attention as safer alternatives due to their superior biocompatibility, lower cytotoxicity, and greater stability in biological environments [4].

In the study, *in vitro* cultures were initiated by transferring inoculum from genetically verified starter strains into 500 mL Erlenmeyer flasks containing Oddoux liquid medium. Cultures were maintained at set temperature under controlled illumination with fixed light/dark cycle. After 21 days of cultivation, corresponding to optimal mycelial growth, the biomass was separated by filtration and freeze-dried at –40 °C.

Chitosan from *P. ostreatus* was obtained using a modified precipitation method. The fungal biomass was demineralized, washed with distilled water, and subsequently deproteinized. Chitosan was then extracted through three microwave-assisted treatments in acidic environment. After centrifugation, strong base was added to the filtrate to induce precipitation. The precipitate was collected by filtration, washed thoroughly with distilled water, and dried. Commercial chitosan was used as a reference material.

Gold nanoparticles were prepared using a reduction technique utilizing chloroauric acid as precursor. The resulting colloidal solution was combined with chitosan samples dispersed in water in equal volumes.

Scanning electron microscopy images revealed visible, even dispersion of AuNPs in extracted chitosan samples, as opposed to agglomerated, uneven dispersion in commercial chitosan. Disc diffusion tests confirmed increased antimicrobial properties against *pseudomonas aeruginosa* bacterial strains. These results indicate that extracted chitosan shows promise as a potential matrix for targeted delivery of gold nanoparticles in wound treatment applications, creating opportunities for more specialized improvements.

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# B9

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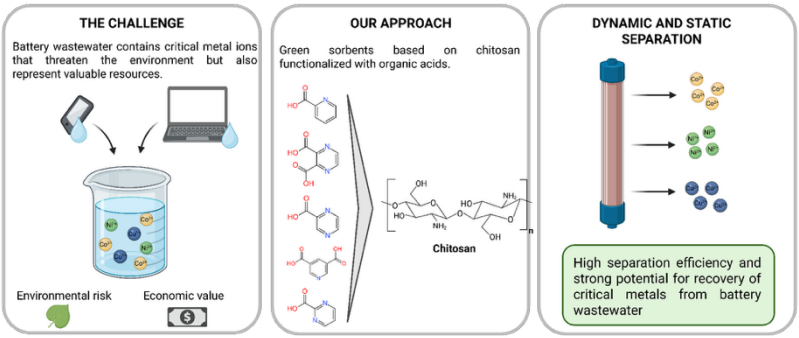
## ORGANIC ACID-FUNCTIONALIZED CHITOSAN FOR THE RECOVERY OF CRITICAL METALS FROM BATTERY WASTEWATER

The growth of the electric vehicle market is increasing the number of end-of-life lithium-ion batteries (LiB). This requires effective, environmentally safe recycling technologies. One method for recovering critical metals from LiB involves hydrometallurgical processes based on leaching and extraction, with recovery rates sometimes exceeding 95% [1]. Unfortunately, this method generates significant volumes of process solutions containing residual metal concentrations, typically ranging from 10 to 500 mg/dm³ (Ni: 100–500 mg/dm$^3$, Co: 50–350 mg/dm$^3$; Cu: 5-100 mg/dm$^3$). Such concentrations are too low for the solutions to be directly recycled into the main process; therefore, they are discharged into sewer systems. From an environmental perspective, they may threaten the aquatic organisms and make it difficult to meet applicable emission standards [2]. One technique that can be used to treat this type of wastewater is sorption, which uses materials to bind these metals. There is an urgent need to identify and investigate the physicochemical properties of new sorbents, with a primary focus on environmentally friendly production technologies.

One such group consists of biopolymer materials derived from nature, the most common of which are chitosan-based materials [3]. Unfortunately, chitosan alone is not suitable for the effective removal of these metals, so it must be chemically modified to increase its sorption capacity and enable selective separation.

This study investigated five organic acids as chitosan functionalizing agents: picolinic acid, 2,3-pyrazinedicarboxylic acid, 2-pyrazinecarboxylic acid, 3,5-pyridinedicarboxylic acid, and 2-pyrimidinecarboxylic acid. The modified sorbents exhibited varying selectivity toward nickel, cobalt, and copper ions, as determined by using these materials in the batch sorption separation of a ternary metal-ion mixture. The highest selectivity coefficients were $K_{Cu/Co} = 657$, $K_{Ni/Cu} = 70$, and $K_{Co/Cu} = 13.9$. These materials were subsequently used in the dynamic and static sorption separation of a ternary metal-ion mixture. This confirmed high separation efficiency and demonstrated the potential of these sorbents for the effective recovery of critical metals from battery wastewater.

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# B10

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## PREDICTING THE ANTIMICROBIAL EFFICACY OF CHITOSAN: A MULTIPLE REGRESSION ANALYSIS OF MOLECULAR WEIGHT AND DEGREE OF DEACETYLATION

Despite the confirmed biocidal potential of chitosan, conflicting data in the literature often make it difficult to determine how its fundamental structural factors, the degree of deacetylation (DD) and molecular weight (MW), jointly determine the minimum inhibitory concentration (MIC). This ambiguity hinders the predictable development of chitosan-based biomedical systems, such as wound dressings [1-2], in which maximizing antimicrobial activity against antibiotic-resistant strains is of critical importance [3].

Based on the fundamentals of polymer physics [4] and standard methods for characterizing macromolecules, this study conducted a quantitative synthesis of data from the literature to create a reliable descriptive framework for tracking the combined and differential effects of polymer technical parameters on the MIC. In accordance with the PRISMA guidelines, a review of multiple databases yielded a highly standardized pool of in vitro studies, each of which provided individual datasets. Chemically insoluble polymer fractions (DD < 60%) were excluded to eliminate systematic bias resulting from limited diffusion in MIC assays [5-6]. Multiple linear regression and stratified subgroup analyses were performed on the final, optimized dataset (N = 106) using spreadsheet-based statistical modeling. The overall multiple regression model proved to be highly significant ($R^2$ = 0.36, $p < 0.0001$), and DD emerged as the dominant factor determining biocidal activity ($p < 0.0001$). After stratification by target cell wall structures, the model's explanatory power consistently increased, yielding an adjusted $R^2$ value of 0.37 for Gram-positive bacteria (N = 46) and 0.38 for Gram-negative bacteria (N = 53), which indicates that biological classification reduces the heterogeneity of the data [7]. Conversely, MW did not show independent statistical significance within the models ($p = 0.156$), acting as a secondary moderating variable rather than a primary linear predictor aligning with *Másson, 2024* [8]. Furthermore, significant systematic gaps in the data were identified. In over 75% of the studies, the pH value of the environment was omitted.

To ensure predictable antimicrobial activity in the industrial and clinical production of biomaterials, it is crucial to prioritize chitosans with high DD. Comprehensive reporting of contextual variables (such as pH and polydispersity) is essential for transitioning chitosan research from descriptive, empirical screening to rigorous, predictable macromolecular engineering.

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# B11

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## FUNGAL CHITOSAN AND γ-POLYGLUTAMIC ACID BIOCOMPOSITE FOR WOUND DRESSING APPLICATIONS

Chronic wounds represent a major and growing clinical challenge, placing a significant burden on both patients and healthcare systems worldwide [1]. Biopolymer-based hydrogel dressings have emerged as a promising therapeutic strategy, providing a moist wound environment conducive to healing while offering opportunities for incorporating bioactive compounds [2]. Such an additive may be chitosan - a deacetylated derivative of chitin - which is particularly attractive due to its antimicrobial activity, biocompatibility and biodegradability [3]. Fungal biomass, especially from *Pleurotus* species cultivated *in vitro*, represents a renewable and controllable alternative source of chitosan with distinctive physicochemical properties, including lower molecular weight, higher degree of deacetylation, and distinct pore structure compared to crustacean-derived counterparts [4,5]. γ-Polyglutamic acid (γ-PGA), a microbially produced anionic biopolymer, demonstrates excellent water retention capacity and biocompatibility, making it a valuable matrix-forming component for wound care applications [6].

The aim of the presented study was to evaluate the combination of chitosan extracted from *in vitro* cultures of *Pleurotus ostreatus* with the addition of γ-PGA acid as a candidate component of hydrogel wound dressings. Chitosan was isolated from *P. ostreatus* mycelium cultivated *in vitro* in the presence of zinc sulfate using a sequential extraction protocol comprising acid demineralization (0.5–1 M HCl, room temperature, 4 h), alkaline deproteinization (5% NaOH, 60–80°C, 5 h), and microwave-assisted extraction with 10% $H_2SO_4$ (3 × 2 min), followed by precipitation with 5% NaOH. γ-PGA was obtained from a glutamine-dependent *Bacillus licheniformis* strain secreting the polymer extracellularly. Biomaterial was prepared by spotting 50 mg of the obtained chitosan with 2 mL of γ-PGA solution, followed by controlled evaporation. The resulting materials were characterized by scanning electron microscopy (SEM) and elemental analysis (Mg, Zn, Fe, Ca, Na, K) using flame atomic absorption spectrometry (FAAS). Antimicrobial activity

was assessed using the disk diffusion method against *Escherichia coli* and *Pseudomonas aeruginosa*.

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# B12

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## RESEARCH INTO HYBRID CHITOSAN HYDROGELS CONTAINING INSULIN IN THE CONTEXT OF POTENTIAL APPLICATIONS IN THE TREATMENT OF CHRONIC WOUNDS

The treatment of slow-healing wounds remains a significant clinical challenge. The healing process consists of closely coordinated stages – inflammation, proliferation and remodelling – the proper progression of which is crucial for effective tissue regeneration. A promising therapeutic strategy is the topical application of insulin, which exhibits pleiotropic effects extending beyond the regulation of carbohydrate metabolism. Insulin can stimulate the proliferation and migration of keratinocytes and fibroblasts, as well as enhance collagen synthesis and modulate inflammation. However, its therapeutic efficacy depends on ensuring adequate stability and sustained release, which justifies the development of advanced delivery systems, such as hydrogels [1].

The aim of this study was to develop insulin-containing hydrogels based on chitosan and cellulose derivatives (methylcellulose, hydroxyethylcellulose, hydroxypropylmethylcellulose). The insulin concentration (Insulatard® Penfill®) in the hydrogels was 1 mg/g. Preformulation studies were conducted, including an assessment of pharmaceutical availability using a Strat-M® membrane simulating the structure of human skin. Rheological measurements were carried out using an RM 200 rotational rheometer, employing a 24 mm diameter plate-plate system. The textural characteristics of the preparations were determined using a TX-700 analyser, with an 8 mm diameter sensor, and by performing a double-compression test.

The hydrogels developed on the basis of chitosan and cellulose derivatives exhibited non-Newtonian flow behaviour with shear-thinning, and their properties were best described by the Herschel–Bulkley model ($R^2 \geq 0.997$). Among the formulations studied, the chitosan–methylcellulose system with insulin was characterised by the highest viscosity, the greatest structural stability and the most favourable textural parameters, including high cohesion and adhesiveness whilst maintaining low hardness. The hydrogels also provided sustained insulin release (highest for the CS/HPMC matrix, 49.0% after 6.5 h). The results obtained confirm that chitosan-cellulose hydrogels, particularly the chitosan-methylcellulose system, represent promising carriers for the topical administration of insulin in the treatment of chronic wounds.

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# B13

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## MICROWAVE-ASSISTED EXTRACTION OF CHITOSAN FROM FILAMENTOUS FUNGAL BIOMASS

Growing interest in sustainable and renewable sources of biopolymers has heightened the importance of fungal biomass as an alternative raw material for chitosan production. Filamentous fungi of the genus *Mucor* represent a particularly promising source of chitin and chitosan, which are key components of their cell walls [1]. The research presented here is a continuation of earlier work conducted at the Institute of Molecular and Industrial Biotechnology at Lodz University of Technology regarding the extraction and characterization of fungal chitosan [2].

Microwave-assisted extraction was employed to recover chitosan from the biomass of *Mucor racemosus* and *Mucor hiemalis*. A comparative evaluation of the microwave-assisted and conventional extraction methods was performed, focusing on extraction efficiency, processing time, and selected physicochemical properties of the resulting chitosan.

It was found that the use of microwave radiation significantly reduced extraction time compared to the conventional method. Despite the shorter process time, the chitosan obtained from both fungal species exhibited physicochemical properties comparable to those of material produced via the conventional method. These results indicate that microwave-assisted extraction is a promising and effective method for obtaining chitosan from both tested filamentous fungi: *M. racemosus* and *M. hiemalis*. They also provide further evidence of the potential of microwave technology for developing more efficient and sustainable methods of producing chitosan from fungal biomass.

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# B14

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## ZINC PHTHALOCYANINE-FUNCTIONALIZED CHITOSAN BIOMATERIAL FOR POTENTIAL WOUND-HEALING APPLICATIONS

The development of multifunctional wound-dressing materials that combine suitable physicochemical properties, biocompatibility, and antimicrobial activity remains an important challenge in biomaterials research. Chitosan is a particularly attractive polymer for this purpose due to its biodegradability, biocompatibility, intrinsic biological activity, and potential to support tissue regeneration [1, 2].

In this study, a porous chitosan-based biomaterial incorporating zinc phthalocyanine was developed for potential wound-healing applications. Chitosan was used as the polymeric matrix, while zinc phthalocyanine was incorporated to enhance the system's biological functionality, particularly its antibacterial performance. The obtained material was characterized in terms of its physicochemical and biological properties. In addition, its interactions with human serum albumin were investigated to provide further insight into the material's behavior in a protein-containing physiological environment.

The developed chitosan/zinc phthalocyanine biomaterial exhibited favorable physicochemical and biological properties relevant to wound-dressing applications. The observed interactions with human serum albumin provided additional insight into the material–protein interface, while combining the chitosan matrix with zinc phthalocyanine yielded a multifunctional system with potential for further development as an advanced wound-dressing material.

Overall, the results support the use of zinc phthalocyanine-functionalized chitosan as a promising platform for designing multifunctional biomaterials for wound management and skin regeneration.

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# *Session C*

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## THE ROLE OF DEEP EUTECTIC SOLVENTS IN TAILORING THE PHYSICOCHEMICAL FEATURES OF CHITOSAN-BASED MATERIALS

Chitosan is an attractive biopolymer for the development of sustainable functional materials because it is bio-based, film-forming, and inherently antimicrobial; however, its dense hydrogen-bond network typically results in brittle materials with limited extensibility and relatively difficult processing. Deep eutectic solvents (DESs), particularly those composed of naturally derived components, offer a practical and mechanistically grounded approach to modifying the physicochemical properties of chitosan. As non-volatile plasticizers, DESs can partially disrupt and reorganize chitosan–chitosan interactions, increase polymer-chain mobility, and substantially improve elongation at break and toughness while simultaneously affecting stiffness, strength, surface characteristics, and barrier properties [1-5]. In addition, their high solvating capacity makes DESs attractive media for the extraction, stabilization, and incorporation of plant-derived bioactive compounds, further extending the functionality of chitosan-based materials.

The concept of the presented work was to develop and comprehensively characterize chitosan films plasticized with hydrophilic DESs by varying both the specific combinations of hydrogen-bond acceptors (HBAs) and hydrogen-bond donors (HBDs) and the DES content. Particular attention was given to the relationship between DES composition and selected physicochemical properties of the resulting materials, including molecular structure, mechanical performance, antioxidant activity, and water vapor permeability.

Overall, the results demonstrate that DES plasticization efficiency is not universal but strongly depends on the specific HBA–HBD combination. Changes in intermolecular interactions induced by DES incorporation were directly reflected in the mechanical and surface properties of the films. The elongation-at-break data indicate a clear hierarchy in plasticization effectiveness driven primarily by the identity of the HBA: ChCl > BET > Pro. This suggests that the accessibility and interaction strength of the acceptor sites within the HBA play a key role in determining how effectively a DES modifies the chitosan network. Consequently, rational selection of DES components provides a versatile strategy for tailoring the physicochemical features of chitosan-based materials toward specific functional applications.

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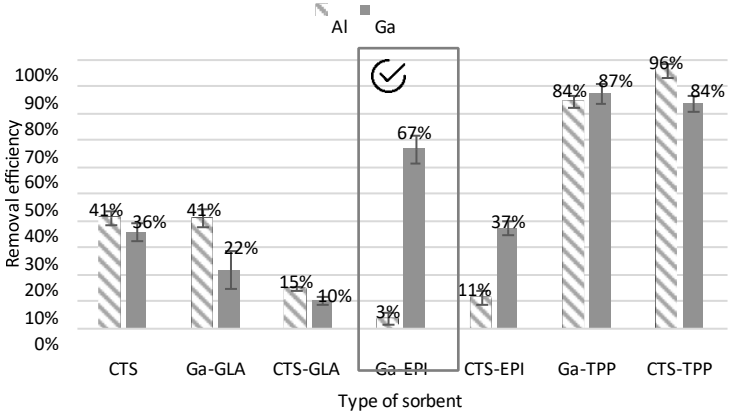
## SEPARATION OF GALLIUM FROM ALUMINIUM IONS USING ION-IMPRINTED CROSS-LINKED CHITOSAN SORBENT

Gallium is a strategic and critical element that plays a vital role in modern technologies. It is used in smartphones, processors, fast chargers, LED lighting, and photovoltaic panels [1].

Gallium does not form its own deposits; therefore, it is usually obtained as a by-product during the processing of bauxite and zinc ores. It can also be recovered from waste electrical and electronic equipment (WEEE). The processing of these raw materials and recovering gallium from WEEE generates complex aqueous solutions from which gallium extraction is difficult, necessitating the development of new recovery methods [2]. Particularly challenging is the separation of gallium ions from aluminium ions due to their chemical similarity [3]. Sustainable approaches—such as sorption processes and materials derived from natural biopolymers—offer promising, low-resource solutions for gallium recovery [4].

This study aimed to develop a sorbent that is selective toward gallium in aqueous solutions containing aluminium ions. Hydrogel-type chitosan sorbents were synthesized using different crosslinking agents and ion imprinting technology in order to identify the sorbent that demonstrated the highest selectivity (figure below). This was an epichlorohydrin-crosslinked chitosan hydrogel with a gallium ion-imprint (Ga-EPI), which was selected for further studies.

The chosen material was characterized in terms of optimal process pH, sorption isotherms and the type and concentration of the most effective desorbing agent. The chemical composition of the sorbents before and after sorption was analysed using Energy-Dispersive X-ray Spectroscopy (EDS), while their morphology was examined by Scanning Electron Microscopy (SEM) analysis. Fourier-Transform Infrared Spectroscopy (FT-IR) analyses were carried out to elucidate the mechanism of gallium binding and to identify the functional groups of the sorbents.

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## CHITOSAN HYDROGEL–POLYMERIC CAPSULE SYSTEM FOR EQUINE DISTAL LIMB WOUND MANAGEMENT

Distal limb wounds are among the most common and challenging injuries in horses due to extensive tissue loss, contamination, delayed healing, and frequent complications. Limited soft tissue coverage, poor vascularization, and constant mechanical stress impair tissue repair, while bacterial colonization further delays healing. Among these lesions, wounds associated with equine pastern dermatitis (EPD) represent a significant clinical problem. EPD is a multifactorial syndrome affecting the distal limb, characterized by nonspecific inflammatory skin lesions of the pastern region. Approximately 40 different underlying causes have been described (parasitic, bacterial, fungal causes include dermatophytes and yeasts), many of which present with similar clinical signs, making diagnosis and treatment challenging. EPD affects horses of all breeds, sexes, and ages and remains an important condition in equine practice [1, 2].

Herein, we present a chitosan-based wound dressing system composed of polymeric capsules incorporated into a chitosan hydrogel and chemically crosslinked using genipin for the future treatment of horses affected by equine pastern dermatitis (EPD). The obtined nanocapsules demonstrated, long-term colloidal stability, and hydrodynamic diameters below 150 nm. Polymeric capsules were incorporated into the hydrogel at the sol stage, prior to the onset of crosslinking, to ensure their homogeneous distribution throughout the material. Three different capsule concentrations were evaluated. Preliminary physicochemical characterization of the obtained systems is currently underway to assess the effect of capsule incorporation on the crosslinking process and the final properties of the hydrogel compared with capsule-free matrices. The evaluation includes swelling and degradation studies, mechanical testing using a microtester, microstructural analysis by scanning electron microscopy (SEM).

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## PULSED ELECTRON DEPOSITION OF GLUCOSE THIN FILMS: THE FIRST STEP TOWARD SOLVENT-FREE DEPOSITION OF POLYSACCHARIDES

Polysaccharide-based thin films have attracted considerable interest for biomedical, sensing, and environmentally sustainable applications due to their biocompatibility, biodegradability, and chemical versatility [1]. However, the fabrication of uniform coatings from polysaccharides, such as cellulose and chitin, remains challenging because of their limited solubility, thermal sensitivity, and susceptibility to structural degradation during processing. These limitations restrict the applicability of many conventional thin-film deposition techniques and motivate the exploration of alternative approaches [2].

In this work, pulsed electron deposition was investigated as a physical vapor deposition technique for the fabrication of glucose thin films. PED is a physical vapor deposition technique based on the interaction between high-energy pulsed electron beams and a target material, resulting in localized ablation and subsequent thin-film formation on a substrate. Unlike laser-based deposition approaches, PED relies on electron-matter interactions rather than photon absorption, which may reduce localized thermal effects and improve the preservation of sensitive molecular structures.[3]

Glucose was selected as a model saccharide to establish deposition conditions and evaluate the feasibility of extending the process to more complex polysaccharides. Thin films were deposited under different accelerating voltages (10-16kV), working argon pressures (6-14 mTorr) and number of pulses (3k-80k). The resulting coatings were characterized by optical microscopy, SEM, AFM, XRD, FTIR, NMR, XPS and contact angle measurements to evaluate their morphology, surface topography, roughness, wettability, crystallisation and chemical structure.

Continuous glucose thin films were successfully deposited under all investigated deposition conditions. Film characterization revealed a strong dependence of surface properties, including roughness and wettability, on the deposition conditions. These characteristics were governed by the combined

effect of the deposition parameters rather than by any individual parameter alone.

The successful deposition and characterization of glucose thin films demonstrate the suitability of PED for saccharide-based materials and establish a model framework for the future deposition and optimization of more complex polysaccharide coatings, including chitosan and chitin-derived materials.

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## FUNCTIONALIZATION OF CHITOSAN WITH POLYPHENOLIC COMPOUNDS TO OBTAIN BIODEGRADABLE MATERIALS WITH ANTIOXIDANT PROPERTIES

Chitosan, obtained by deacetylation of chitin, has attracted increasing attention in recent years due to its biodegradability, biocompatibility, film-forming ability, and antimicrobial properties. The presence of reactive functional groups in its structure enables chemical modifications aimed at improving its physicochemical and functional properties. A promising approach is the incorporation of natural polyphenolic compounds into the chitosan matrix, due to the presence of phenolic groups capable of scavenging free radicals in their structure.

This study focused on the modification of chitosan films through radical grafting of selected polyphenolic compounds to obtain materials with enhanced antioxidant properties. The resulting chitosan-polyphenolic materials were characterized using Fourier Transform Infrared (FTIR) and UV-Vis spectroscopy to confirm the effectiveness of the grafting process and identify structural changes resulting from the modification. Furthermore, the antioxidant properties of the obtained films were assessed using the ABTS and Folin-Ciocalteu tests. Additionally, thermal analysis was performed to investigate changes in the structural organization of the polymer system following the incorporation of polyphenols. The thermal properties of the obtained materials were studied using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) to determine the effect of polyphenol grafting on the thermal stability and phase transitions of the chitosan-based films.

The developed chitosan-polyphenol films represent a promising group of biodegradable active materials with potential applications in functional packaging systems requiring improved antioxidant properties.

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## NON-CROSSLINKED GELLAN GUM-BASED SPONGE REINFORCED WITH MUSA SAPIENTUM AND FUNCTIONALIZED WITH CUCURBITA MAXIMA EXTRACT FOR ANTIOXIDANT AND ANTIBACTERIAL WOUND DRESSING

Most gellan gum (GG) wound dressings incorporating plant extracts, honey, oils, keratin, or secretome still rely on a chemical or physical crosslinker for stability, treating structure and bioactivity as separate choices [1-3]. Here, *Musa sapientum* (MS) peel powder physically reinforces GG through non-covalent entanglement alone, while *Cucurbita maxima* pulp extract adds antioxidant, anti-inflammatory, and antibacterial function to eliminating synthetic crosslinkers entirely. MS alone raised Young's modulus from ~200 to 410 kPa; 20% pumpkin extract (GG-MS@P3) increased it to ~1600 kPa and tensile strength to 34 kPa ($p < 0.0001$), while porosity stayed high (90.3%) and ductility partially recovered (9.5 ± 0.21% elongation), indicating a percolated, stress-dissipating network. GG-MS@P3 reached 84% DPPH scavenging, adsorbed >4.4 mg/cm³ fibrinogen and >4.5 mg/cm³ HSA within one minute, and sustained a ~3-log MRSA reduction at 24 h, matching Bactigras® at 4 h. In vitro, GG-MS@P2 closed scratch wounds fastest, yet in vivo GG-MS@P3 performed best 38.00 ± 1.00% closure by Day 4, 53.33 ± 1.53% by Day 7, 71.33 ± 0.58% by Day 14 showing migration speed alone does not predict healing. All formulations exceeded 90% fibroblast viability at 72 h. Against GG dressings reporting good swelling and healing via physically stabilized network, this system's advance is mechanical self-sufficiency without a synthetic crosslinker.

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