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Extraction Methods for Valorising
Fibers in the Circular Economy

ABSTRACT BOOK

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Session 1

Waste & By-product
Valorization as
Fiber Sources

Advancing Fiber Valorization from Food & Agro-Processing Waste in Kosovo: Scientific, Technological, and Industrial Perspectives

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Valorization of food and agro-processing waste into valuable biopolymers like dietary fibers and polysaccharides offers promising opportunities for sustainable development and circular bioeconomy strategies. In Kosovo, the agricultural sector generates plenty of waste, ranging from fruit pomace, vegetable peels, and cereal bran, but lacks the facilities for the large-scale extraction of these valuable compounds. The paper examines different approaches used in the extraction of dietary fibers, ranging from traditional approaches like hot water and acid hydrolysis to green approaches like enzyme and ultrasound-assisted extraction. The characterization of the dietary fibers shows different functional properties like emulsification, thickening, and antioxidant activities, with waste materials like apple and grape pomace showing promising bioactive activities. However, Kosovo faces major challenges, ranging from the quality of the waste material, legislative challenges, and poor research facilities. To address these, the study proposes the standardization of the extraction process, the harmonization of regulations with EU standards, and the promotion of industry-academia collaborations. The strategic roadmap for the scaling up of the process for the extraction of fibers entails the establishment of pilot sites, the improvement of research capabilities, and the promotion of public-private partnerships. The overall success of the valorization of fibers in Kosovo lies in the integration of research with industry, the establishment of regulations, and the promotion of green technologies.

Dietary fibers from food by-products: up-cycled cocoa bean shells as functional ingredient

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The valorization of food by-products represents a strategic pathway toward more sustainable food systems and is fully aligned with the principles of the circular economy. Among the various agro-industrial residues, cocoa bean shells (CBSs), generated in large quantities during cocoa processing, are particularly promising due to their rich composition in dietary fibers, polyphenols, methylxanthines, and other bioactive compounds [1,2]. Rather than being treated as waste, CBSs can be reinterpreted as an underexploited raw material for the development of functional ingredients with applications in both the food and nutraceutical sectors.

This presentation explores innovative and integrated strategies aimed at transforming CBSs into value-added ingredients with enhanced technological and biological properties. To assess the practical applicability of CBS-derived ingredients, their incorporation into a model food system was evaluated by adding them to muffins at an inclusion level of 7%. CBSs-enriched muffin demonstrated to boost SCFAs and more specifically butyrate concentration in simulated colonic environment. SCFAs are key metabolites associated with intestinal health, immune modulation, and metabolic regulation. These findings highlights favorable technological performance and promising health-related functionality of CBSs [3]

A central focus of the research concerns the improvement of CBS fermentability through targeted enzymatic treatments. These modifications were shown to promote the accessibility of fiber fractions to the gut microbiota, resulting in increased production of SCFAs, key metabolites associated with intestinal health, immune modulation, and metabolic regulation [2]. Such findings support the potential prebiotic role of processed CBSs and highlight their relevance as ingredients for gut health-oriented formulations.

An additional important outcome of this work is the demonstration that fiber modification can be achieved without significant loss of antioxidant compounds. The preservation of these molecules during processing is essential, since it allows CBS-based ingredients to retain their functional value while also improving their physiological performance. This balance between structural modification and bioactive conservation is particularly relevant for the design of multifunctional ingredients capable of delivering both technological and health-promoting benefits [5].

These observations reinforce the feasibility of translating laboratory-scale findings into real food applications, opening opportunities for the formulation of innovative products with added nutritional value.

By advancing extraction, modification, and application strategies, this body of research contributes to waste reduction, resource efficiency, and product innovation, in line with the sustainability goals promoted by the European Green Deal [6]. More broadly, it demonstrates how food by-products can be successfully upcycled into solutions that can promote both human health and environmental sustainability.

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Valorisation of Fruit Waste to Obtain Microalgae Biomass with High Dietary Fiber Content

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The increasing demand for sustainable, functional food ingredients has directed attention toward microalgae as alternative biomass sources rich in dietary fiber. This study aimed to quantitatively evaluate the dietary fiber content of selected microalgal species and assess their *in vitro* digestibility, with a particular focus on their suitability as fiber-rich ingredients. In addition, the study incorporates a sustainability perspective by exploring the valorisation of fruit waste, specifically orange and apple residues, as low-cost substrates for heterotrophic microalgal cultivation.

Microalgal biomasses, including species from *Arthrospira*, *Chlorella*, *Isochrysis*, and *Nannochloropsis*, were cultivated under controlled conditions and harvested at the late exponential growth phase. The biomass was dried and analyzed for total, soluble, and insoluble dietary fiber using standardized enzymatic and gravimetric methods. In parallel, a heterotrophic cultivation strategy was proposed, in which orange and apple processing wastes were pretreated via hydrolysis to produce glucose-rich media capable of supporting microalgal growth under dark conditions. This approach provides a dual benefit of reducing production costs and enabling fruit waste valorisation.

The results demonstrated that microalgae contain substantial levels of dietary fiber, with total dietary fiber (TDF) ranging from 15% to 32% dry weight depending on species. *Chlorella vulgaris* and *Isochrysis galbana* exhibited the highest TDF values (28% and 32%, respectively). In contrast, *Arthrospira platensis* showed a lower TDF content (15%), consistent with its less rigid cell wall structure. *In vitro* digestibility analysis revealed an inverse relationship between dietary fiber content and digestibility. Species with higher insoluble fiber fractions, exhibited lower digestibility values (approximately 55–60%), whereas *Arthrospira platensis* with relatively lower fiber content or less recalcitrant cell walls, showed higher digestibility (up to 75–80%). These findings indicate that while high fiber content may reduce enzymatic accessibility, it also contributes to functional properties such as delayed digestion and potential prebiotic effects.

The integration of fruit waste-derived substrates, particularly from orange and apple residues, offers a promising pathway to enhance sustainability. Heterotrophic growth on these substrates can yield biomass concentrations up to 1.5–2.0 g/L, comparable to or exceeding conventional media, while also influencing cell wall composition. Preliminary observations suggest that cultivation on fruit waste hydrolysates may increase polysaccharide accumulation, potentially enhancing dietary fiber content.

In conclusion, microalgae represent a valuable source of dietary fiber, particularly insoluble fiber, with levels comparable to or exceeding many plant-based ingredients. Their functional properties, combined with the potential for cultivation on orange and apple waste, position microalgae as promising candidates for sustainable, fiber-enriched food applications. This integrated approach supports circular economy principles by coupling fruit waste valorisation with the production of nutritionally enhanced biomass.

Waste to Wellness: Green Valorization of Fruit By-products into Bioactive Fibers for Sustainable Food Systems

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The European agri-food sector generates substantial volumes of fruit processing byproducts that are still largely underutilized, despite their richness in dietary fibers and bioactive phytochemicals. Their valorization represents a key opportunity to support EU priorities on circular bioeconomy, waste reduction, and sustainable food innovation, while contributing to the development of high-added-value functional ingredients.

This study investigates the recovery of fiber-rich fractions from selected fruit-derived residues originating from industrial processing streams, including the confectionery sector. Green and scalable extraction strategies, based on aqueous and enzymatic-assisted treatments, were explored to enhance fiber yield while preserving associated polyphenols and antioxidant compounds. The extracted fractions were characterized in terms of total dietary fiber content, soluble and insoluble fiber distribution, polyphenolic profile, and antioxidant capacity, allowing the identification of promising matrices for targeted food applications.

The results demonstrate significant variability among by-products. Grape pomace and strawberry calyx exhibited high phenolic contents and strong antioxidant activity, confirming their potential as antioxidant-enriched ingredients for functional foods. In contrast, apricot kernels and cherry stems produced fiber fractions with distinctive physicochemical properties, indicating potential applications as texture-modifying and structure-enhancing ingredients. Preliminary functional screening suggests potential prebiotic effects, reinforcing their relevance for gut health-oriented product development.

Overall, this work highlights the potential of fruit by-products as sustainable feedstocks for the production of multifunctional ingredients, bridging environmental benefits with nutritional innovation. By integrating eco-friendly extraction technologies and bioactive compound preservation, this approach supports industrial scalability and contributes to the transition toward resource-efficient food processing. Furthermore, the outcomes provide a basis for future collaborative research within European networks, enabling harmonized methodologies, comparative assessment across processing chains, and the development of standardized valorization pathways aligned with COST objectives.

Keywords: circular bioeconomy, fruit by-products, dietary fiber, polyphenols, green extraction, functional ingredients, industrial scalability

Biochemical conversion of vegetable waste towards biomass and biohydrogen production by *E. coli*

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In this study acid-hydrolyzed mixed vegetable waste was investigated as a sole carbon source for anaerobic growth and biohydrogen (H₂) production by *Escherichia coli*. *E. coli* BW25113 wild type and a septuple mutant lacking key hydrogenase and fermentative enzymes were cultivated during anaerobic fermentative conditions using vegetable waste hydrolysates (VWH) prepared at substrate concentrations of 5–20% (w/v) and varying dilution levels. Both strains were able to grow anaerobically on VWHs, confirming the effective release of fermentable substrates during acid pretreatment. Maximum biomass formation by the wild-type strain reached 0.46 g CDW L⁻¹ in undiluted 20% hydrolysate, while the septuple mutant exhibited improved growth only upon dilution, indicating higher sensitivity to hydrolysate derived inhibitory compounds. Fermentable carbon removal efficiency and H₂ production were strongly dependent on substrate concentration and dilution level. H₂ production was completely suppressed in undiluted hydrolysates but was restored upon dilution, with the highest cumulative H₂ production (406 NmL) observed for the septuple mutant grown on 20% hydrolysate at two-fold dilution. The corresponding H₂ yield reached approximately 2.4 NL H₂ g⁻¹ carbohydrate g⁻¹ biomass or 355 NmL per gram initial carbohydrate. These results demonstrate that VWH can support both biomass formation and competitive H₂ production by *E. coli*, highlighting their potential as a sustainable platform for waste valorization and bioenergy generation.

Session 2

Green Extraction & Processing Technologies

Valorization of Apple Pomace Through Ultrasound and Microwave-Assisted Extraction: Sustainable Technologies for High-Quality Pectin and Dietary Fiber Recovery

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Abstract

Apple pomace, the primary by-product of juice production, represents a significant agro-industrial waste stream rich in dietary fiber (~20% pectin), polyphenols, and bioactive compounds. Despite its nutritional potential, most apple pomace is underutilized, contributing to environmental challenges. This study aimed to develop and optimize sustainable extraction technologies for recovering high-quality pectin and dietary fibers from 'Golden Delicious' apple pomace using unconventional methods, and to demonstrate their application as functional ingredients in food products within a circular bioeconomy framework.

Methods Applied

Two innovative extraction technologies were systematically investigated and compared with conventional methods: (1) Ultrasound-Assisted Extraction (UAE) employing 100% amplitude at 37 kHz frequency, and (2) Microwave-Assisted Extraction (MAE) using magnetron powers of 450 W and 650 W at 2450 MHz. Extraction parameters were optimized through systematic variation of pH (1.0–2.5, adjusted with citric acid), solid-to-liquid ratio (1:10–1:20), and extraction duration (UAE: 15–30 min; MAE: 5–10 min). Physicochemical properties including extraction yield, equivalent mass, methoxyl content, esterification degree, anhydrogalacturonic acid content, total polyphenol content, and antioxidant activity were determined. Extracted pectin was applied as a binding and coating agent in vegetable bars (dried apples, prunes, sour cherries, rosehip powder) and apple pomace powder was used as a sugar substitute (25–100%) in biscuits. Products were evaluated for sensory quality, physicochemical parameters, and microbiological stability during storage.

Main Results Obtained

MAE demonstrated superior extraction efficiency, yielding 19.88% pectin compared to 9.91% from UAE—a 2.01-fold increase. MAE-extracted pectin exhibited 85% higher equivalent mass (1879–2262 g/mol vs. 378–1927 g/mol), while UAE produced pectin with higher methoxyl content (6.81% vs. 6.39%) and esterification degree (73.78% vs. 71.37%). Both methods yielded pectin with comparable total polyphenol content (12.98–13.05 mg GAE/g) and antioxidant activity (16.39–18.86 µmol TE/g). Vegetable bars formulated with MAE-extracted pectin maintained excellent quality over 360 days of storage, with controlled moisture reduction (30.0% to 23.6%), stable pH (3.61 to 3.95), and preserved antioxidant activity (24.85 to 20.14 µmol TE/100g). Biscuits with 25–50% sugar substitution by apple pomace powder showed no significant sensory differences from controls while providing increased dietary fiber content, reduced caloric value, and maintained microbiological stability for 30 days.

Conclusions and Implications

This research demonstrates that unconventional extraction technologies (UAE and MAE) offer sustainable, efficient alternatives to conventional methods for valorizing apple pomace, significantly reducing solvent consumption, energy use, and processing time. The extracted highmethoxyl pectin and dietary fiber-rich powders serve as versatile functional ingredients in food formulations, contributing to product stability, nutritional enhancement, and sensory quality. This work exemplifies circular bioeconomy principles by transforming agro-industrial waste into highvalue ingredients, addressing both environmental sustainability and food innovation challenges within the European food system.

Keywords: apple pomace valorization, ultrasound-assisted extraction, microwave-assisted extraction, dietary fiber, high-methoxyl pectin, circular bioeconomy, functional food ingredients.

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Optical Emission Spectroscopy Monitoring of Reactive Oxygen and Nitrogen Species in Plasma-Assisted Extraction

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Plasma-assisted extraction of bioactive compounds has emerged as a promising technology that meets several criteria for green extractions: reduced solvent consumption, shorter extraction times, lower energy requirements, and suitability for thermolabile compounds. This method uses non-thermal or cold plasma, a partially ionized, non-equilibrium gas composed of electrons, ions, radicals, and photons. Reactive oxygen and nitrogen species (RONS) are generated mainly when energetic electrons, ions, and excited species interact with working gas molecules such as N₂, O₂, and H₂O. These interactions produce short- and long-lived species that can exist in both gas and liquid phases, especially when plasma interacts with moisture or extraction solvents. RONS play an important role in plasma-assisted extractions by participating in the structural modification of biomass, inducing surface etching, pore formation, and cell wall disruption. These effects facilitate mass transfer and solvent penetration, enhancing extraction yields. In the chemical transformation of bioactive compounds, RONS can modify functional groups, affect antioxidant activities, induce oxidation or degradation depending on treatment time and intensity, and break down complex macromolecules into smaller, extractable compounds. The type and concentration of RONS depend on the working gas composition and operating conditions such as voltage, frequency, and treatment time. Monitoring and quantifying RONS is challenging due to the short lifetimes of radicals, which complicate accurate detection, the complex reaction environment in plasma-gas-liquid systems, matrix interference during measurement, and the lack of standardized protocols. Optical emission spectroscopy (OES), a non-invasive diagnostic sensor, is used to monitor and control light emitted by excited atoms and molecules in plasma. OES enables qualitative and quantitative analysis of plasma because each species emits radiation at characteristic wavelengths. Coupling OES with plasma-assisted extraction provides real-time diagnostics, process optimization, and reproducibility. This paper presents OES monitoring of RONS in non-thermal plasma produced in the liquid or gas phase in a glass reactor (volume 300–1000 mL) containing a point-to-plate stainless steel electrode configuration. Plasma is generated by the high voltage electrical discharge (HVED) technique. The high voltage electrical discharge (25 kV, 120 Hz, 1 min treatment time) passes through a capacitor charged with a pulsed high voltage power supply IMPEL HVG60/1 (IMPEL GROUP Ltd., Zagreb, Croatia). Air is used as the working gas, and test measurements to optimize operating conditions are performed with distilled water as a possible solvent. Plasma spectroscopy is conducted using an Ocean FX extended range optical emission spectrometer, model OCEAN-FX-XR1-ES (Ocean Optics, Orlando, FL, USA). Emission from a specific volume in the plasma chamber is collected by transferring optics (an optical fiber with or without a collimating lens) to the spectrometer and, after data processing, to a computer. The detected RONS appear in the expected wavelength ranges: NO (200–300 nm), OH (306–310 nm), and N₂ (300–400 nm). In the NIR region (800–1000 nm), intense emission lines are observed and used to calculate the electron temperature and electron density in the plasma. A deeper understanding of RONS dynamics will support the development of more efficient, selective, and sustainable extraction technologies.

Effect of Microwave-Assisted Hydrolysis and High-Pressure Homogenization on Cellulose Production from Olive Pomace

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Abstract

Olive pomace represents a major agro-industrial by-product with significant potential for valorization within circular bioeconomy frameworks. In this study, a multi-stage processing strategy was developed to convert olive pomace into microcrystalline cellulose (MCC) through the integration of microwave-assisted sulfuric acid hydrolysis and high-pressure homogenization (HPH), and benchmarked against conventional acid hydrolysis.

Conventional treatments were conducted using sulfuric acid concentrations between 5% and 58%, with and without HPH (900 bar). In contrast, microwave-assisted hydrolysis was performed using substantially lower acid concentrations (0.5–1.5 M) and short processing times (1–3 min), followed by HPH at varying pressures (50–900 bar). Structural and morphological transformations were evaluated using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM).

XRD analysis confirmed the preservation of cellulose I structure in all samples, while microwave-assisted treatments resulted in sharper diffraction peaks, indicating enhanced crystallinity despite reduced acid usage. SEM observations revealed that microwave–HPH combinations promoted a more fragmented and fibrillated structure compared to the compact morphology observed in conventional samples. FTIR results further supported the effective removal of lignin and hemicellulose, confirming successful cellulose purification. The application of HPH intensified structural refinement by reducing particle size and improving homogeneity, particularly at higher pressures.

Overall, the combined microwave–HPH approach enabled efficient MCC production under milder chemical conditions and significantly reduced processing times.

Keyword: Olive Pomace, Cellulose, Microwave, High Pressure Homogenization

Recovery of Fibers from Aromatic Plant Residues via Advanced Extraction Technologies

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Medicinal and aromatic plant (MAP) industries generate nearly 30 million tons of waste annually. While these residues are often treated as environmental liabilities, they are actually rich in structural polysaccharides. In a circular economy framework, these solid wastes (SWs) are repurposed as secondary raw materials to extract high-quality natural fibers, reducing the reliance on wood-based cellulose. The fiber quality of plant residues is determined by their proximate composition, typically characterized by cellulose, pectic polysaccharides and lignin. Cellulose is the primary crystalline polymer providing mechanical strength to the fiber. Pectic polysaccharides are the complex, water-soluble fibers (pectin-like) located in the primary cell wall. Lignin is the "glue" that binds cellulose and hemicellulose, which must be managed to access pure fibers. Traditional fiber extraction often involves harsh chemicals and long processing times, but novel green methods like Vacuum Microwave-Assisted Extraction (VMAE) enhance recovery efficiency by using microwave energy to cause "in-situ" pressure buildup and cell wall rupture. Operating under vacuum allows for the preservation of the fiber's structural integrity by preventing thermal degradation while increasing the porosity of the waste for more effective subsequent extraction. For the specific recovery of soluble pectic polysaccharides, Vacuum Microwave Enzyme-Assisted Extraction (VMEE) is employed, combining enzymatic degradation with microwave energy to target pectin-rich regions in alcohol-insoluble residues. The fibers recovered from residues such as Lavender (*Lavandula angustifolia*) and Melissa (*Melissa officinalis*) exhibit specific properties determined by HPLC sugar profiling, which allows them to be used as natural stabilizers in complex systems like double emulsions or to improve the rheological and textural qualities of food products. Transitioning from disposal methods like landfilling or incineration to fiber recovery offers dual benefits by mitigating greenhouse gas emissions and transforming low-cost, deodorized residues into high-value functional ingredients. Ultimately, the sequential use of vacuum and microwave energies represents a breakthrough in green technology, enabling the industry to move toward a zero-waste biorefinery model that prioritizes sustainable, bio-based fiber recovery.

Session 3

Cellulose, Biopolymers
& Advanced Materials

Tuneable bio-based chitosan hydrogels for superaerophobic electrode coatings

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Recent studies¹⁻³ have shown that hydrogels with superaerophobic surfaces represent an effective method for enhancing bubble detachment from electrodes during gas evolution reactions. Efficient bubble removal reduces surface blockage and improves mass transfer, thereby increasing the overall efficiency of electrochemical processes such as water splitting. However, hydrogels developed for this purpose have been primarily petroleum-derived, highlighting the need for sustainable bio-based alternatives.

In this work, sodium periodate was used to oxidize native starch [Figure 1], converting it into dialdehydic starch, a reactive compound capable of forming covalent crosslinks with chitosan. Hydrogel networks were subsequently formed via Schiff-base (imine) bond formation between aldehyde groups of dialdehydic starch and amino groups of chitosan [Figure 2].

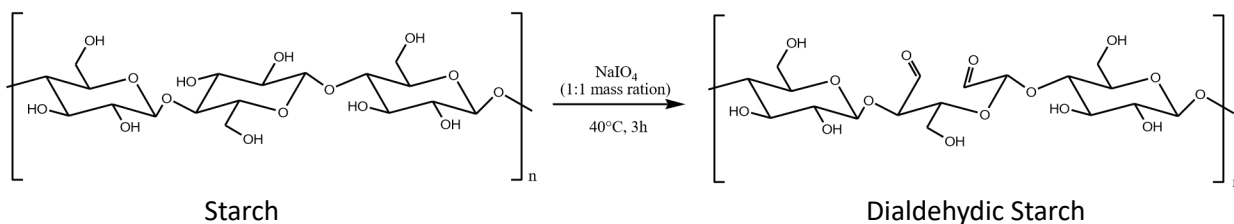


Figure 1: Preparation of dialdehydic starch

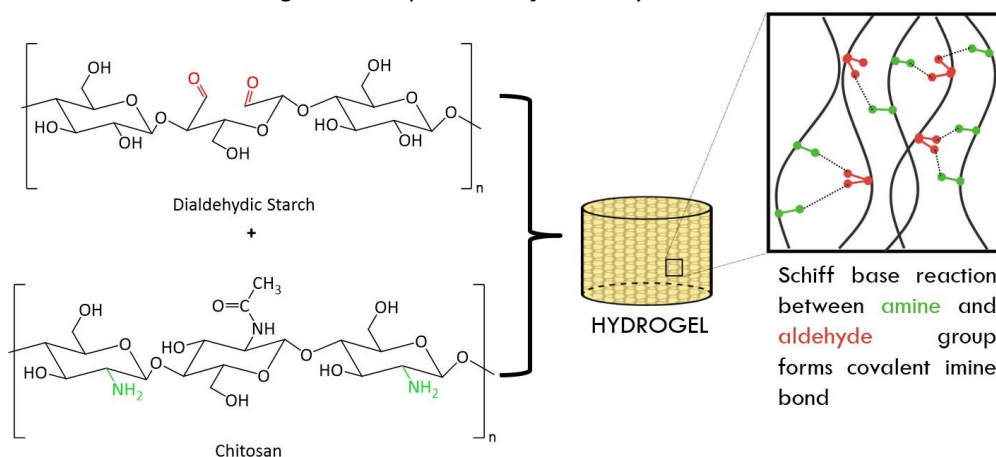


Figure 2: Graphical visualization of hydrogel formation via Schiff-base covalent bonding

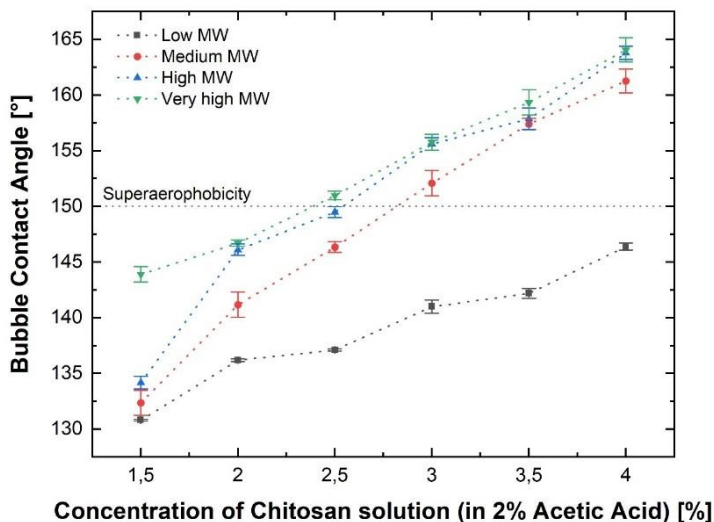


Figure 3: Effect of chitosan parameters on aerophobic properties

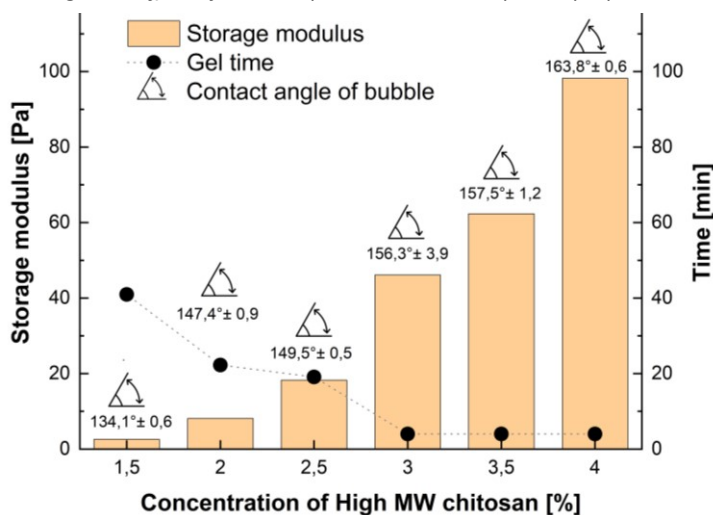


Figure 4: Influence of polymer concentration on gelation time, 30 min storage modulus, and bubble contact angle

under alkaline conditions (pH 12), indicating potential compatibility with typical electrolytes used in water-splitting systems. From a materials perspective, the combination of adjustable network structure, porous morphology, and biobased origin makes these hydrogels a promising platform for further development of functional coatings. Future work will focus on optimizing coating durability and evaluating their long-term performance under electrochemical operating conditions.

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With an appropriate polymer composition and molecular parameters, porous hydrogel materials exhibiting sufficient (super)aerophobicity were obtained [Figure 3], characterized by measuring the underwater bubble contact angle. Such structures promote rapid bubble detachment from electrode surfaces, reducing gas accumulation and improving the accessibility of active catalytic sites.

By varying polymer concentration, the aerophobicity, gelation kinetics, and porosity of the hydrogels could be systematically controlled [Figure 4]. Gelation dynamics, including gelation time and storage modulus (mechanical stiffness), were measured by rheometry.

The ability to tune hydrogel properties is important for optimizing the interaction between the coating and evolving gas bubbles during electrochemical reactions. The materials also demonstrated sufficient stability

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Mechanical, Barrier and Photoprotective Properties of PLA Films Reinforced with Maleic Anhydride–Modified Micro- and Nanofibrillated Cellulose

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Abstract

Poly(lactic acid) (PLA) is a promising biodegradable polymer for food packaging, yet its weak mechanical and barrier properties limit its application. Reinforcing PLA with cellulose fiber is promising, but compatibility is often hindered by the hydrophilic nature of cellulose versus the hydrophobic nature of PLA. To address this, cellulose was modified with maleic anhydride (MA) to form ester bonds with surface hydroxyl groups, reducing polarity. Therefore, this study aimed to develop PLA-based films incorporating 1, 3, and 5 wt% maleic-anhydride-modified microfibrillated cellulose (MMFC) and nanofibrillated cellulose (MNFC) and to systematically evaluate their physical, mechanical, and barrier properties. Both cellulose types were chemically modified through a MA reaction in dimethylformamide at 90 °C for 15 h, followed by ethanol addition, centrifugation, and drying at 60 °C for 16 h. Composite films (1, 3, and 5 wt% MMFC/MNFC) were prepared via solvent-casting in chloroform with 5 wt% polyethylene glycol. Solutions were stirred, ultrasonicated, cast into petri dishes, and dried for 24 h at 25 °C and 50% ERH and characterized.

The thickness of the films ranged from 0.033 to 0.059 mm and increased with cellulose loading. Color analysis revealed increased yellowing and higher ΔE values as cellulose content increased, with the highest ΔE observed in films containing 5% MNFC ($\Delta E = 0.91$). The incorporation of MMFC and MNFC increased water contact angles due to MA-induced esterification of cellulose hydroxyl groups and increased fibril surface roughness, which enhanced surface hydrophobicity. Tensile strength increased from 37.28 MPa for neat PLA to 42.41 MPa and 40.02 MPa for films containing 3% MMFC and MNFC, respectively, while decreasing at 5% loading. Elongation at break remained unchanged at 1–3% incorporation. Heat-seal strength improved from 63.85 N/m for neat PLA to 75.27 and 78.34 N/m for 3% MMFC and MNFC films, respectively. However, 5% loading reduced strength due to fiber aggregation and disruption of matrix continuity. The water vapor transmission rate (WVTR) decreased from 4.44 g/m².24 h for neat PLA to 3.93 g/m².24 h with 3%MMFC and 4.01 g/m².24 h with 3% MNFC indicating a more tortuous pathway for vapor diffusion. However, at 5% loading, WVTR increased likely due to fibril aggregation and the formation of microvoids, which facilitate vapor permeation and disrupt the uniform structure of the matrix. Cellulose incorporation significantly reduced light transmission, particularly in the UV region. Neat PLA showed high transmittance (77.6% UV-C, 81.4% UV-B, 85.6% UV-A, 85.8% visible; 1.69 Abs/mm opacity), while 5% MMFC exhibited the strongest UV blocking effect (56.7%, 61.4%, 64.2%, 64.2%, and 3.47 Abs/mm, respectively). These improvements are attributed to enhanced photon scattering, which reduced UV transmission while maintaining film transparency and improving protection for light-sensitive food products.

Overall, moderate incorporation (1–3%) of modified cellulose fibrils significantly improved the physical, mechanical, barrier, and photoprotective properties of PLA films, whereas excessive loading (5%) caused aggregation and reduced interfacial compatibility. These results highlight the potential of MMFC- and MNFC-reinforced PLA films for sustainable packaging of moisture- and UV-radiation sensitive foods.

Keywords: *Poly(lactic acid), maleic anhydride modification, microfibrillated cellulose, nanofibrillated cellulose, biodegradable films, mechanical and barrier properties.*

Structural, Thermal and Morphological Characterization of Polylactic Acid Composites Incorporated with Chemically Modified Microfibrillated and Nanofibrillated Cellulose

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Abstract

Poly(lactic acid) (PLA), a biodegradable polymer derived from renewable resources, has attracted considerable attention as a sustainable alternative to petroleum-based plastics. However, its relatively low mechanical strength and limited barrier properties restrict its broader application in food packaging. To address these limitations, cellulose fibers were incorporated as reinforcing agents; however, the inherent incompatibility between hydrophilic cellulose and hydrophobic PLA requires surface modification. Therefore, cellulose was modified with maleic anhydride (MA) to form ester bonds with surface hydroxyl groups improving interfacial compatibility with PLA. In this study, biodegradable composite films were prepared by incorporating 1, 3, and 5 wt% MA-modified micro- and nanofibrillated cellulose (MMFC and MNFC) into the PLA matrix. PEG 400 (5%) was used as a plasticizer, and the films were produced via solvent casting. The conditioned films were characterized in terms of their structural (FTIR and XRD), thermal (DSC), and morphological (FE-SEM) properties.

FTIR results confirmed the successful grafting of MA onto the surfaces of MFC and NFC. The low cellulose content caused the overall spectra of the composite films to closely resemble neat PLA, while subtle spectral changes clearly indicated the presence of MA-modified cellulose within the PLA matrix. XRD analysis showed that the characteristic PLA diffraction peaks remained unchanged at 1–3% MMFC and MNFC loadings, whereas increasing the loading to 5% intensified the peak at $2\theta = 22.9^\circ$, suggesting that the fillers acted as nucleating agents and promoted PLA crystallization. DSC revealed that the incorporation of MMFC and MNFC slightly increased the glass transition temperature (T_g) from 57.9 °C (neat PLA) to 60.4–62.8 °C, while the cold crystallization temperature (T_{cc}) decreased from 107.2 °C to as low as 94.9 °C, indicating restricted chain mobility and enhanced nucleation. In contrast, the melting temperature (T_m) remained relatively unchanged within the range of 154.1–159.0 °C. FE-SEM revealed that films containing 1% and 3% MMFC or MNFC exhibited relatively smooth and uniform surfaces, indicating good fiber dispersion and compatibility with the PLA matrix, whereas the addition of 5% filler led to fiber aggregation and rougher surface morphologies. These findings demonstrate that low loadings (1% and 3%) of MMFC and MNFC can effectively improve the thermal, structural and morphological properties of PLA-based films, highlighting their potential for sustainable packaging applications.

Keywords: PLA, Microfibrillated cellulose, nanofibrillated cellulose, maleic anhydride, thermal, structural and morphological properties

Sustainable Multifunctional Hemp-Based Foams via Reversible Citric Acid Crosslinking

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The growing demand for sustainable materials has accelerated the development of bio-based alternatives to petroleum-derived products. We present the design and fabrication of lightweight, multifunctional foams derived from hemp stalk waste and complementary biopolymers and bioproducts, including lignin, xylan, pectin, and glycerol. A freeze-drying approach combined with thermally induced citric acid crosslinking enables the formation of highly porous and tunable foam structures. A total of 25 formulations were investigated to evaluate the influence of composition on structural, mechanical, thermal, and absorption properties. The resulting foams exhibited ultra-low densities (13–153 mg/cm³) and high porosities (up to 99%), with microstructural transitions from nanofibrillar to microfibrillar networks depending on formulation. The materials demonstrated excellent absorption capacities of up to 50 g/g for water, 51 g/g for rapeseed oil, and 46 g/g for kerosene, along with good recyclability over multiple cycles. Thermal conductivity values ranged from 0.040 to 0.046 W/m·K, positioning these foams as competitive candidates for sustainable insulation materials. This work demonstrates a versatile platform for converting agricultural waste into high-performance, biodegradable materials with applications in environmental remediation, filtration, and thermal insulation.

Lignocellulosic fibres – Quantification of fibre morphology and applications in thermoformed products

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RISE PFI

Lignocellulosic fibres have a complex structure that depends on the pulping method applied to obtain them. This includes conventional processes such as kraft and thermomechanical pulping, as well as newer methods, including sulfur-free and DES approaches applied to wood and food biomass side streams.

Fibre structural characterisation involves various methodologies, including optical methods, electron microscopy, atomic force microscopy, and X-ray microtomography. These methods can be applied at different scales to assess fibre dimensions (length and width), fibre splits, fibre collapsibility, fines, and nano-/microfibrils. However, most microscopy assessments reported in the literature have been performed subjectively, primarily based on visual evaluation.

This presentation provides an overview of various microscopy techniques and the required sample preparation, with a focus on computerized image analysis for quantifying the detailed fibre morphology. This development is being further complemented by modern artificial intelligence (AI) approaches to optimize the quantification.

Finally, fibres provide an excellent raw material for the fabrication of plastic-free products, aligning with current efforts to valorise fibres and replace single-use plastic items. Recent examples of 100% thermoformed fibre products are presented.

Session 4

Characterization,
Analytics & Physical
Methods

Magnetic Resonance as a Development and Monitoring Tool for Valorising Fiber

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The family of Magnetic Resonance (MR) techniques encompasses the well-known imaging technique (MRI), chemical shift spectroscopy (NMR) and the less familiar Time Domain Nuclear MR (TDNMR). These complementary techniques have value throughout the whole circular economy of food waste fiber reprocessing. In this work we present two applications of these techniques to demonstrate the diversity in their applicability and their power in supporting the development of new laboratory scale processes, on-line monitoring of production and for quality assurance of raw materials and products. We present early results using a low-cost benchtop TDNMR detected approach to fiber content using enzymatic digestion on apple pomace and compare this to traditional gravimetric analysis, considering methods for improving the speed and accuracy. This has the potential to allow for rapid semi-automated screening of raw materials to estimate fiber content before commencing processing. We also will show how MRI can be applied to functional foods to measure gastric emptying times (which are directly correlated with satiety) for foods prepared with different quantities of fiber. Integrating MRI in this way for functional food (or pharmaceutical) product development allows a more scientific approach to predicting satiety than area under curve of subjective self-reporting. For both of these applications, we will discuss the challenges associated with implementation in the product development cycle alongside their benefits and drawbacks in contrast to more traditional approaches. We will also outline the initial steps needed to integrate such approaches to existing workflows to promote their ongoing adoption in processes which valorise fiber from food waste sources.

Near-Infrared Spectroscopy applications for fiber quantification and characterization as a strategic tool for waste valorization in food and feed systems

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The rapid determination of fiber fractions is essential for the effective revalorisation of agri-food side-streams. As the industry transitions towards a circular economy, the development of valorisation strategies for those fractions diverted into the food and feed waste stream requires precise, real-time chemical profiling to drive the sustainable transformation of residues into valuable resources. Near-Infrared (NIR) spectroscopy provides a rapid, non-destructive and high-throughput analytical solution that support fiber characterisation and facilitates the transition to industrial-scale fibre upcycling. This work reviews research carried out by the Department of Animal Production and the Department of Bromatology and Food Technology of the University of Cordoba (Spain), focusing on the optimisation of NIR applications for fiber analysis across the food and feed value chains. In the animal feed sector, robust calibrations were developed for fiber determination in a wide range of compound feeds (including poultry, cattle, ovine, and equine diets) as well as forage grasses. Model optimisation included the evaluation of pretreatments and the use of linear and non-linear chemometric methods to enhance predictive performance and robustness. Furthermore, the versatility of NIR was demonstrated in complex food matrices, specifically assessing fiber dynamics in asparagus. By examining the influence of cultivars, harvest times, and post-harvest storage (refrigeration and modified atmospheres), it was highlighted how NIR spectroscopy functions as a high-precision tool for evaluating fibre composition. Finally, to ensure industrial feasibility, the critical challenge of calibration transfer is addressed. Effective protocols were established to transfer models between predispersive and postdispersive instruments, as well as from benchtop laboratory devices to portable sensors. This capability is essential for monitoring fiber consistency at the point of waste generation or processing, allowing for the efficient use of the agro-processing waste.

Keywords: Near Infrared Spectroscopy, food and feed sectors, fiber content determination, fast and non-destructive analysis, fiber valorization.

Proposed reviewers of the Scientific Committee: Prof. Mecit Öztop, Middle East Technical University (TR) and Dr. Maria Tarapoulouzi, University of Cyprus (CY).

Microcrystalline Cellulose from Olive Pomace: Effect of Bleaching on Structure, Water Interactions, and Caking Behavior

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Olive pomace, a major by-product of the olive oil industry, is a lignocellulosic biomass that remains largely underutilized despite its potential as a source of cellulose-based materials. The presence of lignin and hemicellulose limits the direct utilization of cellulose from this matrix and purification steps are required to obtain functional cellulose fractions. In this study, the role of bleaching treatment in the production of microcrystalline cellulose (MCC) from olive pomace was investigated. The produced material was characterized in terms of its chemical composition, structural properties, morphology, crystallinity, and thermal behavior using compositional analysis, FTIR spectroscopy, SEM imaging, X-ray diffraction (XRD), and thermogravimetric analysis (TGA). Water–material interactions were further examined through moisture sorption isotherms and time-domain nuclear magnetic resonance (TD-NMR) relaxometry. The results showed that bleaching effectively reduced lignin and hemicellulose fractions and produced a cellulose-rich material with structural characteristics comparable to commercial MCC. In addition, the anticaking performance of the produced MCC was evaluated using an icing sugar model system. Functional evaluation also indicated that the produced MCC reduced caking in icing sugar systems. Overall, the findings demonstrate the potential of olive pomace-derived MCC as a sustainable functional ingredient and highlight the importance of bleaching in improving cellulose purity and performance.

Analytics for characterization of food carbohydrates – dietary fibers

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According to the official AACC definition, dietary fibers (DF) are the edible parts of plants or analogous carbohydrates that are resistant to digestion and adsorption in the human small intestine with complete or partial fermentation in the large intestine. DF include polysaccharides, oligosaccharides, lignin and associated plant substances. Each dietary fiber may display different beneficial physiological effects depending on its structural characteristics. Hence, quantification and adequate characterization of DF present in foods is of utmost importance. Unfortunately, there is not a single method that fulfils all requirements needed to analyse DF.

Briefly, AOAC has established various methods to determine the total DF content, mostly using an enzymatic/gravimetric approach. Oftentimes these methods do not provide information about the type of DF present in a food product. Therefore, an in-depth characterization of DF should be complementary carried out to attain detailed characterization of the DF at stake. To achieve this, various analytical techniques are necessary to study the molecular weight and chemical structure (i.e. sugar composition, glycosidic linkage composition, sugar sequence and organization) of the DF. Chromatography- and mass spectrometry-based methods are mostly employed to characterize DF. In this communication, an overview of the different methods that can be used to characterize DF, from total quantification to extraction and detailed characterization, will be discussed.

Session 5

Bioactive
Properties, Health
& Gut Relevance

Nutritional Fibers from Wood Biomass

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Dietary fibers are indigestible food components associated with multiple health benefits and disease prevention. The average intake of dietary fibers does not meet the nutritional recommendation in Western countries, and therefore new strategies to integrate higher quantities and variations of dietary fibers into our diets are needed. Lignocellulosic biomass has recently been considered a novel and ecologically sustainable source of dietary fibers. Lignin and hemicelluloses represent abundant but underutilized industrial by-products of agriculture and forest industries, whose valorization potential is being actively studied. We have found that lignin and hemicelluloses greatly increase emulsion stability, encouraging their usage in different areas, such as food sciences and oral drug delivery. Furthermore, they exhibit potential health benefits via supporting the growth of beneficial bacteria and suppressing the detrimental ones in the gut, supporting the production of short chain fatty acids and diminishing the production of potentially harmful branched-chain fatty acids. Lignin was metabolized in rat large intestine and some of the metabolites were absorbed into the blood stream and further metabolized to carboxylates, glucuronides, and sulfonates that were measured in the urine. The results increase our understanding of the metabolic fate and potential health effects of dietary fibers and can be used in valorization of lignocellulosic biomass as food ingredients. Wood fibers can be utilized as ecological food stabilizers, supporting holistic valorization of renewable resources including current industrial waste and by-product streams via bioprocesses, to produce diversified value-added end-products.

Engineering a Precise Biocatalyst: Directed Evolution of Inulosucrase for the Production of Tailored Short-Chain Prebiotic Fibers

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The development of "precision prebiotics" requires enzymatic systems capable of synthesizing fibers such as fructooligosaccharides (FOS) with specific degrees of polymerization (DP), as the physiological benefits of these fibers are highly dependent on their chain length. Traditional industrial production using wild-type (WT) fructosyltransferases is often limited by severe substrate inhibition and a lack of control over product distribution. We used protein engineering of an inulosucrase from *Lactobacillus gasseri* (LgFTase) to overcome these industrial hurdles and produce a tailored FOS mixture specifically optimized for gut microbiome modulation. Using directed evolution, multiple generations of LgFTase variants were developed and characterized. In the fifth round of evolution, three lead variants were isolated and shown to possess novel surface mutations that were distal to the active site. Structural modeling via AlphaFold suggested that these mutations improved performance through global structural stabilization rather than direct active-site modification. Notably, a specific variant exhibited a 15-fold increase in the substrate inhibition constant ($K_i = 1450 \text{ mM}$), allowing for efficient operation at high sucrose concentrations. These variants also displayed enhanced operational flexibility, with thermal optima shifted to while maintaining a precise product profile of DP 3–7. To facilitate scalable production, the engineered enzymes were immobilized on a Sepharose matrix in a continuous-flow system. This configuration allowed for the steady-state synthesis of FOS with enriched short-chain proportions (DP 3–7), effectively limiting the formation of long-chain polymers. Characterization of the produced FOS via HPLC confirmed a consistent and reproducible product composition across varying flow rates. The biological efficacy of these tailored fibers was evaluated using *in vitro* anaerobic fermentation models with human fecal samples and specific gut-associated bacterial taxa. The enzymatically synthesized FOS induced a significant drop in pH and a marked increase in the production of health-promoting short-chain fatty acids (SCFAs), particularly acetate and butyrate. While this research focuses on the enzymatic synthesis from sucrose, the robustness and high-temperature stability of these engineered variants offer a promising technological bridge for agricultural waste valorization. Such biocatalysts could potentially be implemented to transform sucrose-rich side streams from agricultural processing into high-value, structurally defined prebiotic fibers, aligning enzymatic precision with sustainable waste-to-fiber strategies.

Strategies to obtain polysaccharides from *Agaricus bisporus* by-products for the development of hypocholesterolemic food ingredients

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Driven their unique organoleptic properties and a growing demand for healthy, vegan, and high protein foods, mushroom consumption was expanding at a robust rate of 10% per year globally^[1]. The global mushroom market size was 19.65 Ktons^[2], from which approximately 60 Ktons are by-products, which are currently used as fertilizer or feed^[3]. Given that these by-products are a rich source of proteins and polysaccharides, specifically β -glucans which possesses potential hypocholesterolemic activity^[4,5] they represent a significant opportunity for high value potation.

In this work, extraction and characterization of different fractions containing polysaccharides and proteins from *Agaricus bisporus* by-products was addressed targeting its valorisation as functional ingredients, with potential hypocholesterolemic effects.

Ethanollic, aqueous and alkaline extracts of *Agaricus bisporus* by-products resulted in low yield of soluble (29%) and high yield of insoluble (54%) polysaccharides. The fractions are rich in carbohydrates (37-83%) being glucose the major monosaccharide residue (44-96 mol%) determined by GC-FID of alditol acetates derivatives. The water insoluble residue (WIR) resulting from hot water extraction was shown to be composed by 53% carbohydrates from which 69 mol% was glucose and 19mol% was glucosamine. This corresponds to 39% yield of initial mushroom where the insoluble glucan contains similar quantities of (1 \rightarrow 4)-Glc (30 mol%) and (1 \rightarrow 6)-Glc (23 mol%) determined by glycosidic linkages analysis using GC-MS. Furthermore, this fraction also comprises the presence of 28 mol% of protein as well as (1 \rightarrow 4)-GlcNAc (11 mol%) and t-GlcNAc (1 mol%) linkages characteristic of chitin. This residue was submitted to alkali extraction (NaOH 1M) leading to a supernatant (Sn_1M.NaOH) rich in carbohydrates (83%) mainly glucose (96 mol%) with a yield of 16% regarding to the initial mushroom. The characteristic glycosidic linkages profile was (1 \rightarrow 4)-Glc (43 mol%) and (1 \rightarrow 6)-Glc (26 mol%). From the supernatant dialysis a precipitate (ppt_Sn1M.NaOH) was obtained amounting 57% of carbohydrates from which 94mol% was glucose. The yield obtained was 3% of initial mushroom being the characteristic glycosidic linkages the following (1 \rightarrow 3)-Glc (39 mol%) and (1 \rightarrow 4)-Glc (24 mol%). The residue (R_1M.NaOH) obtained was composed by 60 % of carbohydrates with 53 mol% of glucose and 42mol% of glucosamine. The yield obtained was 12% of the initial mushroom with (1 \rightarrow 3)-Glc (5 mol%), (1 \rightarrow 4)Glc (6 mol%) and (1 \rightarrow 6)-Glc (12 mol%), characteristic linkages of β -glucans, together with (1 \rightarrow 4)GlcNAc (25 mol%), configuring an enrichment of chitin.

To access hypocholesterolemic potential, the effect of characterized fractions on cholesterol bioaccessibility using a simplified in vitro intestinal model was studied. The results show that ppt_Sn1M.NaOH decreased 5% of cholesterol bioaccessibility contrary to the other fractions. This decrease was related with the higher content of (1 \rightarrow 3)-Glc of this fraction. Indeed, using as positive control a mixed linked β (1 \rightarrow 3)/(1 \rightarrow 4)-glucans from oat and barley, which are well accepted as cholesterol reducing ingredients by EFSA also show a decrease of 72-78% in cholesterol solubility, highlighting the relevance of structures containing together β (1 \rightarrow 3)-Glc and (1 \rightarrow 4)-Glc on this activity. The strategy that allowed to obtain the β -glucan structures with hypocholesterolemic potential was alkaline extraction followed by neutralization and dialysis of supernatant.

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Chitosan as natural biofungicides for the management of fungal diseases of fresh fruit, grapevine and of seedborne pathogens

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Growing consumer demand for residue-free food, retailer commitments, stricter policies aimed at reducing synthetic chemical pesticides use, and the expansion of organic agriculture are driving research toward safer and more sustainable crop protection strategies. At the same time, plant diseases are estimated to cost the global economy more than USD 220 billion annually, reducing crop yield and quality while contributing to food price increases and food insecurity. Among the most promising alternatives, chitosan has emerged as a versatile bio-based tool for plant protection. Chitosan [β -(1,4)-2-amino-2-deoxy-D-glucose] is a natural biopolymer obtained by the deacetylation of chitin, the second most abundant polysaccharide in nature after cellulose. Chitosan is recognised for its antimicrobial activity, elicitation of plant defence responses, and its ability to form protective films and coatings. Our studies demonstrated that chitosan can be effectively applied along the entire crop chain, from seed to postharvest stages. In seed treatments, chitosan showed effective control of the main seedborne pathogens of cabbage, including *Alternaria alternata* and *Alternaria brassicicola*. Under field conditions, it showed efficacy against grapevine downy mildew and powdery mildew, caused by *Plasmopara viticola* and *Erysiphe necator* respectively. In postharvest applications, chitosan reduced fruit decay caused by *Botrytis cinerea* and *Monilinia* spp., while contributing to improved fruit preservation. These results confirm the broad-spectrum potential of chitosan as a sustainable alternative to conventional pesticides. However, further large-scale validation trials are needed to optimise dosages, formulations, and application strategies under diverse crops, environmental conditions, and production systems.

Keywords: Antifungal activity, Chitosan, Seedborne, pre and postharvest disease

Tomato-Derived Functional Foods with Enhanced Antitumor Activity

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This study evaluates the antitumorigenic efficacy of innovative functionalized tomato products, specifically leathers and snack bars. The biological activity was assessed using MTT cell viability assays across a diverse panel of human cancer cell lines, including Caco2 (colon adenocarcinoma), HT29 (colorectal adenocarcinoma), SKMEL30 (melanoma), and U87MG (glioblastoma).

Experimental results revealed a significant, dose-dependent reduction in cell viability across all tested cell lines. While lower concentrations (1 mg/ml) showed negligible inhibitory effects, higher concentrations (5 mg/ml and 10 mg/ml) led to substantial growth suppression. The antitumorigenic potency was significantly influenced by the specific product formulation. Baseline tomato sauce (TS) formulations exhibited the lowest inhibitory activity, whereas products fortified with olive powder (O) and plant-derived proteins, such as Rubisco (R) or Pea (P) protein, demonstrated enhanced efficacy.

The most potent effects were observed at the 10 mg/ml concentration, particularly in formulations containing both olive powder and protein additives (TS+O+R and TS+O+P). The HT29 and Caco2 colon cancer lines appeared particularly sensitive, with viability dropping as low as 40–50% in certain protein-enriched snack bar and leather treatments. These findings indicate that the strategic enrichment of tomato-based functional foods with olive and plant proteins provides a synergistic inhibitory effect on cancer cell proliferation, suggesting high potential for these products as health-promoting dietary interventions.

Comparative Functional and Bioactive Characterization of Beetroot and Raspberry By-Product Extracts under Ultrasound-Assisted Extraction

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The valorization of fruit and vegetable by-products offers a sustainable pathway for obtaining bioactive compounds with functional potential. This study investigates beetroot and raspberry by-product powders as sources of natural antioxidants and pigments, focusing on their characterization, functionality, and bioactive properties. Ultrasound-assisted extraction (UAE) was applied under identical conditions with varying temperature, time, and ultrasound power to evaluate differences in extraction performance. The extracts were characterized in terms of antioxidant activity (DPPH, ABTS), total phenolic and flavonoid contents, pigment yield, color parameters (CIELAB), and UV–Vis spectra, while molecular weight distribution was assessed by HPLC–SEC. Raw materials were analyzed using FTIR, SEM, and ICP–OES to understand their structural and compositional influence.

Raspberry extracts showed higher flavonoid content (390–530 mg CE/100 g) and antioxidant activity, while beetroot exhibited superior pigment yield. Principal component analysis (PCA) explained 75.1% of the total variance which revealed clear separation of samples according to both plant matrix and extraction treatment, highlighting differences between bioactivity-driven and pigment-driven extraction trends. Results highlight that intrinsic material properties govern extract functionality, supporting the sustainable use of agro-industrial by-products as bioactive ingredients.

Session 6

Fermentation,
Single-Cell Proteins
& Novel Food
Ingredients

From Bio-Based Polysaccharides to Functional Aerogels for Food Applications

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The transition towards a circular bioeconomy places a strong emphasis on extracting and utilizing natural fibers to create sustainable, high-value materials. To support these goals, this study explores how extracted bio-based polysaccharides, specifically chitosan, sodium alginate and xanthan gum, can be transformed into advanced aerogels for applications in food processing. Supercritical CO₂ drying is a key step in the development of these functional materials. Unlike other drying methods, which often cause structural collapse, this advanced technique protects the fragile, three-dimensional network of biopolymers. Operating under gentle conditions, it produces highly porous, low-density materials without leaving behind any harmful solvent residues, making it an environmentally friendly and safe process for food-grade applications. The resulting aerogels have large surface areas and adjustable water absorption properties, which allow them to perform effectively in diverse, complex environments. In practical food systems, these bio-based materials have proven highly efficient as adsorbents in liquid processing. They have been successfully used to clarify beverages such as iced tea and to safely remove oxidation products from used frying oil for regeneration. Furthermore, their open porous structure provides an effective microenvironment for enzyme immobilization, significantly improving stability, accessibility, and reusability of enzymes during food processing. Thus, integrating natural polysaccharide fibers with advanced supercritical drying techniques could offer a practical, scalable way to add value to bio-based resources, contributing directly to more sustainable, circular food technologies.

Bioconversion of Fiber-Rich Agro-Food Residues into *Yarrowia lipolytica* Biomass: Comparative Evaluation of Acid Hydrolysates for Sustainable Food-Grade Biomass Production

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The valorization of fiber-rich agro-food residues is an important strategy for developing sustainable bioprocesses within the circular bioeconomy. The aim of this study was to evaluate selected lignocellulosic by-products as alternative carbon sources for microbial biomass production by *Yarrowia lipolytica* KKP 379. Four agro-industrial residues, namely tea waste, wheat straw, sugar beet pulp, and orange peels, were subjected to acid hydrolysis and compared for their initial reducing sugar content, sugar utilization during cultivation, and ability to support yeast biomass formation.

Hydrolysates were prepared with 1% H₂SO₄ and used as cultivation media in both non-supplemented and supplemented variants. A medium containing 4% glucose served as the control. The initial concentration of reducing sugars in the hydrolysates was measured before cultivation. Shake-flask cultures were conducted, and samples were collected at 24, 72, and 120 h to monitor residual sugars and biomass production.

The tested hydrolysates differed markedly in their initial reducing sugar content. Sugar beet pulp hydrolysate contained the highest level of reducing sugars (44.51 ± 6.55 g/L), followed by orange peel hydrolysate (37.64 ± 1.17 g/L). Wheat straw and tea waste hydrolysates showed substantially lower values, 12.99 ± 0.39 g/L and 8.34 ± 0.33 g/L, respectively. These differences were reflected in yeast growth. Among all tested substrates, sugar beet pulp hydrolysate proved to be the most effective for biomass production. In the supplemented medium, biomass reached 12.20 g/L after 72 h and remained high at 10.50 g/L after 120 h. Orange peel hydrolysate also supported efficient growth, yielding 10.05 g/L biomass in the supplemented variant after 120 h. In contrast, tea waste and wheat straw hydrolysates were less effective in non-supplemented media, but supplementation significantly improved biomass production, increasing the final biomass from 3.86 to 6.97 g/L in tea waste hydrolysate and from 1.37 to 5.08 g/L in wheat straw hydrolysate. The glucose control reached 10.86 g/L biomass after 120 h.

The results demonstrate that fiber-rich agro-food residues can be effectively upgraded via hydrolysis and bioconversion into value-added microbial biomass. Among the tested materials, sugar beet pulp showed the greatest potential as a low-cost substrate for *Y. lipolytica* cultivation, and nutrient supplementation substantially improved the performance of low-sugar hydrolysates. These findings support the use of agro-industrial residues as promising feedstocks for sustainable biomass production.

Keywords: *Yarrowia lipolytica*, biomass, food waste, lignocellulose

Single-cell protein biomass as a sustainable source of protein and dietary fiber: nutritional, technological, and bioactive properties of *Saccharomyces cerevisiae* and *Fusarium venenatum*

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Background:

Reducing the consumption of animal-based products and developing innovative, sustainable, ethical, nutritious, and health-promoting alternatives has become a global priority. Single-cell proteins (SCP) are alternative proteins produced through the fermentation of microorganisms, such as yeast, filamentous fungi, bacteria, and algae. These sustainable protein sources exhibit rapid growth and productivity and can be cultivated using industrial by-products, contributing to a low carbon footprint and supporting circular economy strategies. Beyond high protein content, SCP biomass presents a valuable nutritional profile, particularly due to the presence of dietary fiber components derived from microbial cell walls, including β -glucans and chitin. Yeasts, especially *Saccharomyces cerevisiae* (SC), are one of the most extensively studied and industrially explored microorganisms for SCP production, largely due to their well-established use in the food and biotechnology industries. Regarding microbe-derived proteins, mycoproteins from filamentous fungi such as *Fusarium venenatum* (FV) have gained increasing attention due to their meat-like texture (e.g. Quorn™ products)[1]. This study aimed to produce and characterize SC and FV biomass at a pilot scale and evaluate their potential as functional food ingredients for the development of nutrient-rich products.

Methodology:

SCP biomass was produced through controlled fermentation at pilot plant scale using a BIOSTAT Cplus fermenter, with total and working volumes of 30 and 20 L, respectively. Proximate composition was determined according to AOAC standard methods. Chemical characterization included the quantification of total dietary fiber and glucans using enzymatic assay kits. Mineral composition was analyzed by inductively coupled plasma (ICP), while amino acid and fatty acid profiles were determined by high-performance liquid chromatography (HPLC) and gas chromatography with flame ionization detection (GC-FID), respectively. Additionally, antioxidant capacity (ABTS and ORAC) as well as ACE and α -glucosidase inhibitory activities were evaluated. Technological properties, including water and oil holding capacities, foaming and emulsifying properties, were also assessed.

Findings:

SC exhibited a higher total protein content (32.06% of dry weight-DW) compared to FV (16.35% DW), with similar protein solubilization levels (45.64-43.67%). Total (45.20% DW), insoluble (38.43% DW), and soluble (6.77% DW) dietary fiber were also higher in SC, with β -glucan and α -glucan concentrations of 7.35 and 16.73% DW, respectively. FV exhibited higher fat (4.70% DW) and ash (7.75% DW) content. FV biomass is an excellent source of phosphorus, potassium, and magnesium, as well as oleic, linoleic, and palmitic acid. Both species showed balanced amino acid profiles, with high levels of essential amino acids.

The results also suggest that SC possesses higher antioxidant capacity, namely 70.55 and 109.66 μmol Trolox equivalent (TE)/g DW for ABTS and ORAC, respectively. In contrast, FV exhibited

stronger anti-hypertensive potential (IC_{50} of 20.88 $\mu\text{g}/\text{mL}$). SC exhibited higher α -glucosidase inhibitory activity (36% at 68 mg/mL). Regarding technological properties, FV showed a higher water and oil holding capacity, while both biomasses presented comparable foaming properties and good emulsifying capacity.

Conclusions:

This study demonstrated that both biomasses possess relevant nutritional, functional, and technological properties, reinforcing the potential of SCP as a sustainable functional ingredient. Future work will focus on product development, as well as bioaccessibility, bioavailability, and associated health benefits.

Topics: Characterization, functionality, and bioactive potential of extracted fibers

Keywords: Single-cell proteins; *Saccharomyces cerevisiae*; *Fusarium venenatum*; Functional ingredients.

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Cross-sector valorization: Agro-industrial and Sea by-products into protein and bioactive properties enhancement *Aspergillus oryzae*-driven solid-state fermentation

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Introduction: The agro-industrial sector represents a rich source of lignocellulosic residues with significant valorization potential through bioprocessing strategies, particularly when utilized as carbon sources to support microbial activity. Specifically, agro-industrial residues such as pineapple, lemon peel, acorn peel, grape pomace and coffee spent grounds within the SSF matrix can improve substrate porosity, enhance nutrient availability, and provide additional bioactive precursors to be released through enzymatic activity. Additionally, the potential incorporation of sea by-products (*Spirulina platensis*) introduces a nitrogen rich component that can effectively balance the carbon/nitrogen (C/N) ratio of the matrix, thereby enhancing microbial growth and metabolic performance, promoting circular bioeconomy strategies for resource efficient and sustainable bioprocesses. In this study, five different agro-industrial residues were mixed with *S. platensis* by-product (SPSB) as substrate for *A. oryzae* bioprocessing, following by the evaluation of protein content and antioxidant activity.

Methodology: The evaluation englobed the compatibility of the microorganism (radial growth evaluation, water absorption index (WAI), critical moisture point (CMP) and pH); following, a 120 h fermentation was performed according to previously optimized conditions (previously stage). Then, antioxidant activity (ABTS and FRAP), flavonoid content, and total protein content (Kjedahl) [1].

Results: The evaluation of the by-products potential as substrates revealed low pH values (3.51 ± 0.01 – 5.143 ± 0.03). Additionally, the WAI and CMP values fall within the range reported in the literature as suitable for the development of solid-state bioprocesses. Regarding radial growth assessment, similar growth rates (mm/h) were observed compared to those reported for other by-products in the literature for *Aspergillus* spp., with the highest growth rates obtained for lemon peel (0.36 ± 0.06), grape pomace (0.37 ± 0.06), and coffee spent grounds (0.35 ± 0.06), which can be explained by their rich nutritional composition [2]. Also, the antioxidant activity and the flavonoid content increased at least 2 times (ABTS, FRAP and Flavonoids), and the total protein content of fermented biomass increase between 20 – 50 %. Given these promising results, the study was conducted to maximize the valorisation showing the best combination to reach higher antioxidant activity.

Conclusion: This research aims to valorize agro-industrial by-products and microalgae residues for the development of novel biofunctional ingredient while promoting sustainable bioprocessing approaches by industrial symbiosis.

Key words: Agro-industrial by-products, Industrial symbiosis, Sustainable biorefinery, Novel proteins.

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Session 7

Scale-Up,
Sustainability,
Standardization
& Policy

New challenges in the risk assessment of fiber rich ingredients as food additives in Europe

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In the recent years, an emerging practice involves substituting synthetic food additives with plant-derived bioactive chemicals, primarily obtained from plant-based products and by-products, in line with the principles of sustainability and the circular economy. This is the case of fiber rich ingredients, that can be authorized by the European Commission to be applied as thickeners, gelling agents, stabilizers, among others, as food additives.

The risk assessment for food additives is a multi-step scientific process to ensure public safety by identifying hazards and evaluating exposure to potential risks. It involves the evaluation of new food additive composition, how it interacts with food, its potential toxicological effects and the estimation of the potential exposure along the diet of the European consumers.

Since 2026, each new food additives applications must follow the Guidance on the scientific data requirements for an application for authorization of a food additive submitted under Regulation (EC) No. 1331/2008. All new food additives based on fiber rich extracts are consider as complex mixtures, this makes its risk assessment somewhat challenging, especially when it comes to identifying potential risks and evaluating their impact.

In this sense, the new approach in the risk assessment of fiber rich extracts will be reviewed paying special attention to the key points to be consider for it possible application as a new food additive in Europe. Moreover, some examples of fiber rich new food applications recently assessed by the EFSA will be highlighted.

From fiber products to platform chemicals: Scale-Up perspectives from the University of Hohenheim Biorefinery

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Protein extraction from green biomass creates more than one valuable side stream. Alongside the protein fraction, it also generates a fiber-rich press cake and sugar-rich brown juice that can support further product development. At the University of Hohenheim, these streams are being considered within an integrated biorefinery approach. The press cake offers potential as a raw material for fiber-based products and materials, while the brown juice can serve as a feedstock for platform chemicals such as 5-HMF and levulinic acid. The Hohenheim biorefinery concept shows that both streams are produced in relevant amounts, which makes them interesting not only scientifically but also from a future scale-up and application perspective.

This work focuses on the scale-up perspective of linking these routes instead of treating the remaining streams as low-value residues. The aim is to move beyond single-product thinking and to improve the overall efficiency and relevance of green biomass biorefineries. In this context, fiber valorization and chemical valorization should not be seen as competing options, but as connected pathways that can strengthen each other. A biorefinery that produces feeding for animals, fiber products and platform chemicals from the same biomass has a stronger basis for industrial interest, regional implementation and long-term economic viability. The broader concept also matches the goals of reducing imported feed dependence, improving circularity, and creating more value from agricultural side streams. Work carried out at the University of Hohenheim already provides a useful basis for this discussion. In the grass biorefinery process, brown juice was identified as a promising second-generation sugar source for hydrothermal conversion, while the solid side stream remains relevant for material-oriented routes. In lab-scale trials, the brown juice contained about 104 g/L total sugar and the conversion experiments showed that 5-HMF formation started at around 160 °C. The highest 5-HMF production was reached about 5 minutes after the system reached 200 °C, while levulinic acid increased later in the process. These results are important because they show that side streams from biomass fractionation can already deliver technically meaningful intermediates, but they also make clear that further optimization is still needed before moving toward larger-scale implementation.

This work also highlighted several practical questions that are highly relevant for scale-up. Further conditioning of the brown juice is needed to remove remaining components that may intensify carbonization and additional dilution is required because the sugar concentration in the raw stream is higher than what is typically used in practice. In addition, the experiments showed that process reproducibility and reactor reliability matter strongly for obtaining robust results, which is exactly the kind of issue that becomes even more important when moving from lab work to pilot or technical scale.

From an industry perspective, the key question is how such side streams can move from promising laboratory materials to reliable process inputs. This includes handling variation in biomass quality, improving stream stability and consistency, identifying realistic product routes for fibers and chemicals, and integrating these valorization steps into existing processing lines. By combining fiber use with platform chemical production, the University of Hohenheim's approach shows how green biomass biorefineries can move beyond a single-output model and develop into broader value-chain systems. This is where scale-up becomes especially important: not only as a technical step, but as a framework for connecting research results, industrial needs and regional bioeconomy opportunities.

Poster Presentations

Health Benefits of Dietary Fiber from Macadamia Oil and Brazil Nut Processing By-Products

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The increasing interest in sustainable food production has led to growing attention toward the valorization of agro-industrial by-products. Residues generated during the production of macadamia oil and the processing of Brazil nuts represent valuable sources of dietary fiber and other bioactive compounds. These by-products contain significant amounts of insoluble and soluble fibers that can contribute to improved gastrointestinal health, regulation of blood glucose levels, and reduction of cholesterol absorption. Dietary fibers derived from macadamia and Brazil nut residues may also support the growth of beneficial gut microbiota, thereby promoting overall metabolic health. In addition, the presence of associated phytochemicals and antioxidants may enhance their functional properties and provide protective effects against oxidative stress. The incorporation of such fiber-rich by-products into food formulations offers a promising approach for developing functional foods while simultaneously reducing food waste and improving the sustainability of nut processing industries. Therefore, the utilization of macadamia oil and Brazil nut processing residues as sources of dietary fiber represents a valuable strategy for both nutritional improvement and circular economy development in the food sector.

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Understanding Starch Dissolution in Deep Eutectic Solvents: From Water–DES Interactions to Extraction from Potato Peel Waste

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One of the growing ecological challenges is the transition from fossil-based resources to renewable and sustainable alternatives. Biomass is increasingly recognised as a promising feedstock for developing sustainable industrial processes. Among the various types of biomass, starch-rich materials are of particular interest due to their wide range of potential applications. However, extracting starch from these sources remains challenging, as structural properties and solubility behaviour can significantly affect extraction efficiency and often result in low yields. Potato peelings, often overlooked as a by-product of the food processing industry, are a rich source of starch and therefore present an interesting opportunity for valorisation. Their starch content, which constitutes a significant fraction of their composition, makes them a promising resource for starch recovery. Deep eutectic solvents (DES) have recently emerged as an alternative approach for biomass processing, as they can be tailored for specific applications, including the dissolution of poorly soluble biopolymers such as starch. The precise combination of hydrogen bond acceptors (HBAs) and hydrogen bond donors (HBDs) can significantly influence solvent–solute interactions and thus enhance starch solubility. In this work, DES composed of generally recognised as safe (GRAS) compounds were designed and investigated. The dissolution behaviour of starch in DES systems was studied to better understand the underlying solubilisation mechanisms. In particular, the influence of water on the solvent structure was examined by investigating both water-in-DES and DES-in-water regimes. Hansen Solubility Parameters, which characterise solvent polarity and affinity towards solutes, were used to support the selection of suitable HBA:HBD combinations for improving starch solubility. Based on these findings, the most promising DES systems were subsequently applied to the extraction of starch from potato peels. This approach contributes to improving the utilisation of potato peel waste while providing further insight into starch dissolution in DES media and supporting the development of more sustainable extraction strategies.

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Sustainable Micellar Extraction of Curcuminoids from *Curcuma longa*

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Downstream processing is a critical component of production across many industries. However, these processes are often complex, energy-intensive, and require significant material input, which means they can account for up to 80% of overall production costs. As industries increasingly pursue sustainable and cost-effective solutions, the development of innovative downstream processing techniques has become essential for improving efficiency while maintaining high productivity. In this context, this study introduces a more sustainable approach for extracting curcuminoids from *Curcuma longa* using micellar solutions. The proposed method combines solid–liquid extraction (SLE) and liquid–liquid extraction (LLE) into a single integrated process, improving overall efficiency. The SLE solvent, composed of a buffer and a biodegradable surfactant, enables the formation of an aqueous micellar two-phase system (AMTPS), which represents a specialized form of LLE. Optimization of both SLE and LLE conditions resulted in a curcuminoid recovery exceeding 95% in the surfactant-rich phase. Beyond efficient extraction, the findings also highlight the potential of these systems for smart packaging applications. The surfactant-rich phase demonstrates strong stability, maintaining its structural integrity for more than 50 hours under UV exposure with only about 20% degradation. These systems were also successfully applied for paper dyeing, where mixed AMTPS produced more intense coloration with increasing ionic liquid concentration, in contrast to conventional systems without ionic liquids, in which increasing concentration did not enhance color intensity. Overall, these findings demonstrate the capability of this approach to support the development of sustainable materials with practical real-world applications.

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Optimisation of Enzymatic and Processing Conditions for the Recovery of Bioactive Phenolics from Olive Pomace

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Keywords: olive pomace, bioactive compounds, metabisulfite, enzymatic inhibition, phenolic preservation

Introduction

The extraction of bioactive compounds from olive mill waste has gained significant attention due to their potential health benefits and sustainability implications [1]. Enzymatic hydrolysis, particularly using pectinase, has shown promise in enhancing the release of these compounds [2]. This study aims to optimize enzymatic parameters through factorial experimental designs and evaluate the influence of sulphur dioxide and drying temperature on extraction efficiency, and assess phenolic and antioxidant activity through specific assays.

Methodology

Olive pomace was stabilised by freeze-drying at -80°C or by sodium metabisulfite treatment (10–20%), followed by homogenisation, after which full factorial designs were applied to optimise extraction conditions. In Experiment 1, enzymatic extraction using pectinase was evaluated by varying temperature (25–60°C), pH (3–5), and enzyme concentration (0–10%) over 3 hours. In Experiment 2, the combined effects of drying temperature (40–80°C), sulphur dioxide (0–20%), and enzyme ratio (0–10%) were assessed over 24 hours to examine preservation and thermal influences. In Experiment 3, the role of the chemical environment was investigated using buffer systems across pH 2.0–9.2 and ethanol–buffer mixtures (20–70% v/v) at room temperature for 2 hours. All extracts were subsequently analysed using spectrophotometric assays and validated HPLC methods to determine phenolic composition and antioxidant activity.

Results

In Experiment 1, TPC and TFC were maximised at moderate temperature (40°C), pH 5, and high enzyme levels, confirming enhanced enzymatic release of phenolics, whereas high temperature without enzyme reduced extraction; in contrast, TdOPC and FRAP were highest at low temperature (25°C) and pH 5 without enzyme, indicating greater stability under mild conditions, while CUPRAC showed partial dependence on enzyme concentration. In Experiment 2, TPC increased at higher temperature (80°C), suggesting thermal release, whereas TFC and TdOPC were maximised at 60°C with high SO_2 and enzyme, highlighting the stabilising effect of SO_2 and the negative impact of excessive heat. In Experiment 3, extraction efficiency was governed by pH and solvent composition, with acidic conditions favouring TFC and procyanidins, TdOPC and CUPRAC were enhanced at moderate pH and higher ethanol levels, while yield increased under alkaline conditions due to improved mass transfer.

Conclusion

Phenolic extraction from olive pomace is controlled by enzymatic conditions, temperature, and extraction chemistry. Moderate temperatures with enzyme enhance TPC and TFC, while mild conditions favour TdOPC stability and antioxidant activity. Thermal treatment increases release but can

cause degradation unless stabilised by SO₂. Extraction efficiency is further governed by pH and solvent composition, with compound-specific responses.

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Understanding the effect of extrusion on fiber and phenolic compounds of strawberry pomace in starch-based extrudates

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Poster presentation

Strawberry byproducts (SBP), i.e. pomace, generated during juice extraction, are rich in fiber and phenolic compounds, offering potential for functional ingredients. This study evaluated the hypothesis that interactions between fiber and phenolic compounds in extruded snacks may confer to phenolic compounds a protection against extrusion-induced degradation. The study was designed to test this through controlled snack formulations with tapioca starch: either SBP, isolated cell wall, isolated phenolic extracts, or a combination between cell walls and phenolic compounds. Mid-Infrared spectroscopy (FTIR), microscopy (SEM), and chemical analysis confirmed that extrusion significantly reduced anthocyanins and flavonoids, except kaempferol-3-O-glucuronide and (-)-epicatechin for which content increased under certain conditions. Regarding, cell wall composition rhamnogalacturonans were the most affected, while hemicelluloses and cellulose remained stable. Cell wall presence favored proanthocyanidin retention, especially highly polymerized forms of flavan-3-ol units. These findings highlight the cell wall role in conferring phenolic compounds protection against extrusion-induced degradation. This new knowledge opens avenues for optimizing extrusion processes to enhance the nutritional quality of plant-based products, particularly those incorporating phenolic-rich byproducts.

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Extraction of soluble dietary fiber from red beetroot waste for encapsulation and delivery of the antimicrobial peptide nisin

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Beet processing generates large amounts of waste, particularly pomace, which is rich in dietary fiber and whose potential benefits remain largely unexplored. Soluble dietary fiber extracted from red beetroot waste can be utilized to produce higher-value products, thereby promoting the sustainable use of agricultural resources. The purpose of this work was to extract soluble dietary fiber from beetroot pomace and to evaluate its suitability for nisin encapsulation. Nisin is a well-known peptide composed of 34 amino acid residues. It is synthesised by the food-grade lactic acid bacterium *Lactococcus lactis* subsp. *lactis*. Nisin is active against Gram-positive bacteria, including *Clostridium botulinum* and *Listeria monocytogenes*. It is approved by the US Food and Drug Administration for its applications in food products and assigned the number E234 as a food additive in the EU.

The beetroot pomace used for the extraction of soluble dietary fiber was freeze-dried and powdered. A conventional extraction method and two non-conventional techniques, microwave-assisted extraction and pulsed ultrasound-assisted extraction, were used and optimized. Finally, the extracted soluble fiber was precipitated with isopropyl alcohol and dried. The extraction yields were 12.3%, 3.1% and 7.1%, respectively. The solubility of the dried extracts was analyzed and was found to be 27.4 ± 1.4 mg/mL. The total carbohydrate content was determined in the obtained dried extracts and was found to be equal to 938 ± 42 mg/g. FT-IR analysis showed the presence of pectin in the soluble fiber fraction. Analysis using the Bradford method did not detect any protein impurities. Dynamic light scattering showed that the obtained material had a negative surface charge at a large range of pH value. Preliminary experiments demonstrated that the extracted soluble fiber could be used to encapsulate the antimicrobial peptide nisin.

Valorization of Bilberry Pomace as a Fiber-Rich Material for Sustainable Paper Production

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Agro-industrial residues such as fruit pomace are an abundant yet underutilized source of lignocellulosic fibers for material applications. In this study, bilberry (*Vaccinium myrtillus* L.) pomace was investigated as a renewable, fiber-rich material for paper production. The study aimed to determine the fiber composition of bilberry pomace and evaluate its suitability for papermaking. The pomace was analyzed for cellulose, hemicellulose, and lignin content using established analytical methods. Paper sheets were produced in a laboratory sheet-forming system by partially replacing cellulose pulp with bilberry pomace (BP1–BP3). The resulting materials were evaluated for basic mechanical and optical properties. Incorporating bilberry pomace enabled the production of visually distinctive papers with a characteristic light blue color from naturally present anthocyanins and a slightly grainy texture. Pomace addition affected both mechanical and optical properties; higher incorporation levels reduced tensile strength, whereas lower levels enabled the production of functional materials with acceptable properties. Compared to extract-based approaches, direct utilization of pomace resulted in more pronounced modifications of both structural and visual characteristics. Overall, the results show that bilberry pomace is a promising fiber-rich material, particularly as a source of structural polysaccharides, and can be used for specialty paper production by partial substitution of conventional pulp. This approach supports the valorization of agro-industrial residues and advances circular bioeconomy strategies.

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Incorporation of passion fruit by-product as functional ingredient in gluten-free flours: effect on dietary fiber and arabinoxylans content

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During the last years, there has been an increasing focus on developing gluten-free snacks using pulse-cereal blends enriched with different sources of dietary fiber obtained from agro-industrial by-products. Besides their nutritional value and functional properties, pulses are notable to promote sustainable food systems. The functional quality, and specifically the fiber content of extruded snacks made from pulses can be improved by incorporating fruit by-products (peels, leaves, seeds, pulp waste), and passion fruit skin has emerged as a key ingredient in this field. Since the juice industry discards nearly half of the fruit's mass (closed to 50%), revalorizing these nutrient-dense peels not only minimizes environmental impact but also adds significant nutritional value to new food formulations. This work aimed to investigate the influence of fiber-rich ingredients incorporation, particularly passion fruit skin and Fibersol[®], on the dietary fiber (total, soluble and insoluble) and arabinoxylans (total and water soluble) content of different rice-chickpea blends (raw and extruded), destined to the elaboration of gluten-free, snack-type products. Total dietary fiber and their fraction (soluble and insoluble) were quantified by applying official AOAC enzymatic–gravimetric methods 993.19 and 991.42. Arabinoxylans (total and water-soluble) were estimated following a colorimetric method. Despite the complexity of the analyzed food matrices, the statistical analysis carried out consisted of the inclusion in the ANOVA of two-way interactions, demonstrated that the individual fortification with passion fruit significantly impacted the arabinoxylan content (total and water-soluble), as well as the insoluble dietary fiber fraction. These outcomes have implications for health, as arabinoxylans have demonstrated potential benefits for control of several diseases, including diabetes and cardiovascular diseases. Moreover, insoluble dietary fiber is essential to the normal function of the intestinal tract. The obtained results suggested that passion fruit by-products let enhance the composition of different pulse-cereal blends, constituting an interesting way to improve the food quality of gluten-free snacks-type products.

Two biodegradable biopolymers from carbohydrates of *Ulva rigida* seaweed

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Abstract

The environmental issues caused by petrochemical plastics, along with the growing awareness of society on these matters, highlight the urgent need to develop materials with similar properties that are both environmentally and economically viable¹. Macroalgae can be the source for these materials. Sulfated polysaccharides, such as ulvan from *Ulva* genus (7-29 % d.w.basis)^{2 3} emerge as alternatives for film production⁴. However, to ensure their practical application, namely in food packaging solutions, it is necessary to develop formulations to improve film properties such as low mechanical resistance and water-solubility⁵.

On the other end the biopolyesters- polyhydroxyalkanoates (PHA), produced by bacteria are excellent candidates, offering physical and mechanical properties comparable to conventional plastics⁶. However, they are not economically viable, as the primary cost driver is the carbon sources required for bacterial growth⁷.

In this study, *Ulva rigida* carbohydrates were upgraded to ulvan films and PHAs. Ulvan was extracted from the cell walls through hot water treatment. The ulvan was recovered via precipitation using ethanol and integrated into a film matrix along with sodium carboxymethyl cellulose (CMC), pectin or sodium alginate and glycerol as plasticizer. The films composed of ulvan, CMC, and glycerol demonstrated the best mechanical properties. However, ulvan alone did not exhibit the ability to form viable films.

The remaining seaweed carbohydrates were pre-treated by autohydrolysis in a pressure reactor and the recovered solids enzymatically treated to glucose-rich hydrolysates. These were incorporated into culture media as the sole carbon source in preliminary shake flask assays using *Halomonas halophila* as PHA-producer. These assays have shown this halophile to be tolerant towards potential inhibitors produced during the hydrolysis (HMF- hydroxymethyl furfural) and to have a high capacity to produce P3HB.

Fed-batch cultivations were carried out in a 300 mL reactor with *H. halophila*, using the hydrolysate as the sole carbon source in the feed. A maximum production of 33.8 g/L and a maximum productivity of 0.23 g/L/h of P3HB were recorded, with no statistically significant differences compared to the control.

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Screening Agro-Industrial By-Products as Promising Feedstocks for the Valorisation of Upcycled Antioxidant Dietary Fibre

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Abstract:

Agro-industrial by-products represent promising raw materials for the valorisation of antioxidant dietary fibre (ADF)-rich ingredients within circular food systems. ADF refers to dietary fibre matrices intrinsically associated with antioxidant compounds, mainly polyphenols, which may contribute to both bioactive and techno-functional properties. Despite their potential, the suitability of agro-industrial side streams as sources of upcycled ADF is highly matrix-dependent, varying according to fibre composition, structural organisation, and the nature of associated phenolic compounds. The identification of the most promising sources, therefore, requires an integrated evaluation encompassing fibre composition, structural features, functional behaviour, and phenolic-associated bioactivity. In this work, a comparative multi-matrix approach was applied to screen plant-based side streams and identify those with the greatest potential for the future production of upcycled ADF concentrates.

Six by-product matrices - olive pomace, apple pomace, pruning vine, almond hulls, brewer's spent grain, and tomato pomace - were dried and milled using a rotor mill followed by a cyclone mill. Samples were characterised for particle-size distribution and dietary fibre fractionation, including total dietary fibre (TDF), insoluble dietary fibre (IDF), and soluble dietary fibre (SDF). Fourier-transform infrared spectroscopy (FTIR) was used to assess the main functional groups across matrices. Techno-functional properties were evaluated through water retention capacity (WRC), swelling capacity (SC), water solubility index (WSI), and oil retention capacity (ORC) (Jagelavičiūtė *et al.*, 2025; Yu *et al.*, 2018). Bioactivity was assessed through total phenolic content (TPC) and antioxidant capacity (AOX), considering free and bound phenolic fractions (Marçal *et al.*, 2024). Principal component analysis (PCA) was applied to explore relationships among all evaluated parameters.

All by-products exhibited high TDF contents (approximately 38-79%), with IDF as the predominant fraction (approximately 32-76%). Pruning vine and olive pomace showed the highest IDF levels (approximately 75.4% and 50.4%, respectively), while apple pomace and tomato pomace presented higher SDF contents (approximately 15.4% and 11.2%, respectively). Particle size distribution also differed markedly: almond hulls and olive pomace were enriched in fine particles (<50 µm), whereas tomato pomace was dominated by coarser fractions (150-250 µm). Almond hulls and tomato pomace exhibited the highest WRC (approximately 19.5 and 18.3 g/g, respectively), apple pomace the highest SC (approximately 3.5 mL/g), and pruning vine the highest ORC.

Regarding bioactivity, olive pomace presented the highest AOX (approximately 659.4 µmol TEAC/g dw), followed by pruning vine (approximately 535.4 µmol TEAC/g dw) and almond hulls (approximately 378.5 µmol TEAC/g dw). TPC was highest in almond hulls and olive pomace, with notable contributions from the bound phenolic fraction. Although higher TPC was generally associated with higher AOX, pruning vine displayed elevated antioxidant activity despite moderate TPC levels, suggesting

differences in the individual potency of its phenolic profile (Karastergiou *et al.*, 2024). PCA revealed clear discrimination among matrices, reflecting integrated differences across all evaluated parameters. Overall, these by-products displayed matrix-dependent profiles in fibre composition, particle size, functional properties, and phenolic-associated bioactivity, supporting their differentiated selection for specific extraction strategies and applications. These findings provide a robust screening framework for the future valorisation of upcycled ADF concentrates with potential relevance for gut health promotion.

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Production of Value-Added Bioactive Fibers from Beverage Industry Diatomite Filtration Wastes via Microbial Fermentation: A Circular Biorefinery Approach

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When evaluating food wastes, filter aids which are generally not subjected to any recovery process pose a significant environmental challenge. Diatomite (kieselguhr), a natural mineral of biological origin, is an organic sediment composed of fossilized siliceous shells of microscopic algae known as "diatoms". Subjected to calcination, this material is widely used in the beverage industry for sugar syrup filtration. By adding it to the filtered liquid in a controlled dosing manner, the filter cake's porosity is maintained, achieving the desired clarification. However, a high-organic-load "diatomite mud" waste emerges post-process, which is often left unutilized.

In this study, an integrated biorefinery model was initiated to recover the aforementioned waste for the production of value-added products. In the initial stage, the waste sludge was centrifuged at 5000 rpm for 15 minutes, separating into an inorganic silica-containing pellet and a supernatant with a significantly high organic load. Analyses revealed that the supernatant fraction contained sugar syrup with a value of 60 Brix. Comprehensive microbiological analyses (Total Viable Count at 22°C and 37°C, *E. coli*/Coliform, and Yeast) of the raw diatomite sand, pellet, and supernatant fractions were completed. While the microbial load in the raw material and pellet was zero (0), total viable counts and yeast growth were observed in the supernatant. Microbial identification tests detected *Sphingomonas paucimobilis*, *Staphylococcus vitulinus*, and *Candida pelliculosa*. To pave the way for controlled biotechnological processes, this contaminated supernatant was sterilized in an autoclave at 121°C for 15 minutes.

In the planned biotechnological phases, this supernatant will be diluted (to ~5 Brix) and its pH adjusted (4.5-5.5) to create a suitable bio-matrix. Submerged and mixotrophic fermentation processes will be initiated using halotolerant microalgae/cyanobacteria (*Dunaliella* sp., *Halotheca* sp.) or *Saccharomyces cerevisiae* to convert free carbon into bioactive polysaccharides. Different microorganisms can also be evaluated. Following fermentation, two organism-based purification protocols are designed for downstream processing. In the microalgae route, extracellular EPS fibers will be purified through cold ethanol precipitation and lyophilization. In the alternative yeast route, insoluble cell-wall Beta-(1,3)/(1,6)-Glucan fibers will be isolated post-harvest utilizing microwave-assisted green extraction (MAE) and controlled cell lysis without toxic solvents.

Anticipated data will confirm that the diluted waste is an ideal bio-matrix for microbial fiber synthesis without external nutrient supplementation. The produced polysaccharide fractions will function as "clean label" nutraceutical fibers exhibiting immunomodulatory and thickening properties in beverage formulations. Consequently, this research aims for the *in-situ* biological synthesis of fibers from waste sugars, presenting an innovative alternative to obtaining fibers from lignocellulosic sources through harsh chemical methods. Ultimately, by transforming a costly industrial burden into high-value functional ingredients, this integrated biorefinery approach pioneers a sustainable, zero-waste circular bioeconomy model for the beverage sector.