polysaccharides

Editorial

Recent Progress on Lignocellulosic-Based Materials

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1. Introduction

The term *progress* can be broadly divided into two complementary categories: *technical progress* and *technological progress*. Technical progress includes advancements and refinements in equipment, methods, and procedures that improve productivity, efficiency, accuracy, and overall operational performance; in essence, it reflects *process innovation*. Technological progress, by contrast, refers to the translation of these advances into new products, materials, functionalities, and applications; in essence, it reflects *product innovation*.

In the field of lignocellulosic-based materials, these concepts can be adapted accordingly. Technical progress includes improvements in biomass pretreatment, extraction, modification, separation, characterization, processing, and manufacturing methods. Technological progress, in turn, concerns the development of novel lignocellulosic-based materials, enhanced functionalities, and innovative applications.

This Special Issue aimed to provide a forum for the dissemination of recent advances in lignocellulosic-based materials, spanning both technical progress in biomass characterization, fractionation, and processing and technological progress in the development of novel materials, functionalities, and applications.

2. Highlights from This Special Issue

2.1. Technical Progress—Process Innovation

An effective method for determining the absolute molecular weight of cellulose using a multi-angle light scattering (MALS) detector in a solvent system consisting of 99% dimethyl sulfoxide and 1% 1-ethyl-3-methylimidazolium acetate (DMSO/EmimOAc) was proposed by Ola Sundman [1]. The approach enables characterization of cellulose in solution by ensuring efficient dissolution in the ionic liquid/DMSO system, allowing accurate analysis of molecular weight distributions and absolute molar mass without reliance on calibration standards.

In their review, Stanciu and coworkers [2] highlighted the effectiveness of FT-IR and X-ray diffraction spectroscopy for assessing the crystallinity of different cellulose substrates, as they provide fast and reliable results, can be used in both qualitative and quantitative studies, and involve simple and straightforward procedures. Furthermore, these techniques enable the analysis of not only raw materials and final products but also intermediate stages of processing, allowing the monitoring of structural transformations throughout the entire process. Their combined application provides valuable information on changes in cellulose supramolecular architecture, including polymorphic transitions and variations in crystallinity, thereby offering a robust approach for evaluating cellulose modification and hydrolysis processes.

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The recent advances (2020–2025) in the mechanical pretreatment of plant biomass, covering fundamental mechanisms, hybrid approaches, energy efficiency, life cycle assessment, and industrial scalability, were reviewed by Podgorbunskikh and co-workers [3]. Their analysis demonstrated that mechanical pretreatment is far more than a simple particle-size reduction step, as it can induce profound structural changes in lignocellulosic biomass, including disruption of the lignin–carbohydrate matrix, reduction in cellulose crystallinity, increased specific surface area, enhanced porosity, and the generation of reactive sites. The authors emphasized that hybrid strategies combining mechanical action with chemical, physicochemical, or biological treatments often exhibit synergistic effects, leading to improved biomass deconstruction and higher conversion efficiencies. Depending on the desired products—such as biofuels, bio-oils, fermentable sugars, biopolymers, platform chemicals, or advanced functional materials—mechanical technologies including hammer milling, knife milling, ball milling, extrusion, and ultrafine grinding can be integrated with thermochemical, chemical, or enzymatic processes. The review also highlighted the importance of optimizing energy consumption and process economics to facilitate industrial implementation, identifying mechano-catalytic and integrated biorefinery approaches as particularly promising directions for sustainable biomass valorization.

Puițel and co-workers [4] proposed an efficient strategy for the extraction and purification of hemicellulosic polysaccharides from corn stalks based on alkaline treatment followed by a sequence of physicochemical separation and purification steps, including selective precipitation and ion-exchange chromatography using Purolite A400, Purolite A100+, and Purolite C100H resins. Their study demonstrated that the purification sequence strongly influences both hemicellulose recovery and product quality, as the removal of lignin-derived compounds, salts, proteins, and other low-molecular-weight impurities is essential for obtaining highly purified fractions. The optimal protocol consisted of soda pulping, acid precipitation at pH 4.5, anion-exchange treatment with Purolite A100+, a first ethanol precipitation step, cation-exchange treatment with Purolite C100H, and a second ethanol precipitation. This approach resulted in the highest hemicellulose recovery yield and purity while preserving the polysaccharide structure, highlighting its potential for the production of hemicellulose-rich fractions suitable for further valorization in biorefinery, food, pharmaceutical, and biomaterials applications.

Biorefining is the primary force behind the recent advances in lignocellulosic-based materials, enabling the sustainable fractionation of cellulose, hemicellulose, and lignin into high-value biomaterials. From this perspective, Puitel and co-workers [5] performed a comparative evaluation of two abundant agricultural residues, rapeseed straw (RS) and sunflower stalk (SS), both generated in large quantities as by-products of oil crop production. The study investigated their potential as renewable feedstocks within a biorefinery framework, aiming at the simultaneous recovery of hemicelluloses, lignin, and cellulose-rich fiber fractions. The proposed biorefining approach, effective for both RS and SS, was based on a combination of soda pulping and alkaline extraction processes, enabling efficient fractionation and valorization of the main structural components of lignocellulosic material.

2.2. Product Innovation

Packaging materials have attracted significant attention from researchers [6], particularly due to advances in bio-based multifunctional materials with improved performance and sustainability. Ramdani and co-workers [7] developed and characterized biocomposites incorporating cellulose fibers derived from alfa grass (*Stipa tenacissima*) into a polyurethane (PU) matrix synthesized from jojoba oil, obtaining materials with potential applications in packaging, automotive, biomedical, and textile fields. In a related study, Nechita and co-workers [8] investigated acetylated xylan as a functional coating com-

ponent for biodegradable paper-based food packaging; multilayer systems combining acetylated xylan with chitosan and ZnO nanoparticles resulted in biodegradable, antimicrobial, and high-performance coatings suitable for sustainable food packaging applications. Camarena-Bononad and collaborators [9] studied PLA-based composites reinforced with lignocellulosic fibers from *Posidonia oceanica*, showing that up to 5 wt% fiber improves oxygen barrier properties but affects color and transparency, while bleaching treatments reduced mechanical performance (stiffness, modulus, and tensile strength), with untreated fibers providing the most balanced overall properties for packaging use. Additionally, Sabo and co-workers [10] evaluated cellulose-based coatings for copy paper using cellulose nanocrystals, oxidized cellulose nanofibrils, and carboxymethyl cellulose, demonstrating improved grease, oxygen, and air barrier performance relevant for paper-based packaging applications.

Biocomposites, in which lignocellulosic fibers and/or biomass-derived particulates are incorporated as reinforcing agents or functional fillers [11], contributing to enhanced mechanical performance, interfacial adhesion, and overall composite functionality, is another important class of materials that attracted researchers' attention. Nakyp and co-workers [12] investigated lignocellulosic powder from alfalfa biomass as a sustainable filler in nitrile–butadiene rubber (NBR) composites. The filler effectively reinforced the rubber matrix while partially replacing conventional mineral fillers, leading to environmentally friendlier elastomeric materials. The resulting composites showed suitable mechanical and swelling properties for sealing applications, including casing elements, gaskets, and swelling tapes. In a related study, Castona-Rivera and co-workers [13] evaluated lignocellulosic microfibers (LCMFs) from recycled paper and cardboard as alternatives to carbon black and silica in natural rubber composites. The LCMFs improved hardness, tear strength, and abrasion resistance, confirming their reinforcing potential while reducing reliance on non-renewable fillers and supporting circular-economy approaches. Vu and co-workers [14] proposed a direct and sustainable approach for the production of cellulose nanocrystals (CNCs) with a high crystallinity index (68.9%) using a deep eutectic solvent (DES) system based on zinc chloride and choline chloride. The DES treatment enabled the selective removal of amorphous cellulose domains while preserving the crystalline regions, yielding CNCs with desirable structural and morphological characteristics. Furthermore, the obtained nanocrystals were successfully functionalized through acetylation, which reduced their hydrophilicity and allowed the surface properties of the CNCs to be tailored over a broad range. This surface modification enhances their compatibility with hydrophobic polymer matrices and expands their potential applications in nanocomposites and other advanced bio-based materials.

Biomass-derived materials can also find applications as *food additives*, as shown by the study conducted by Herrera-Balandrano and co-workers [15]. They investigated the use of feruloylated arabinoxylans (FAXs) extracted from nixtamalized maize bran as a functional ingredient in white bread. Their findings indicated that FAX incorporation positively influenced the physicochemical and functional properties of the bread, with improvements observed in texture, hardness, chewiness, fiber content, and antioxidant capacity, ultimately enhancing overall bread quality.

3. Conclusions and Outlook on Future Developments

This Special Issue, "Recent Progress on Lignocellulosic-Based Materials", highlights the rapid transition of lignocellulosic biomass from low-value agricultural and industrial residues into versatile feedstocks for advanced materials and chemical production [16]. Across the contributions, efficient biorefining strategies—particularly alkaline extraction, soda pulping, and hybrid chemo-mechanical treatments—are shown to enable effective

fractionation of cellulose, hemicellulose, and lignin from diverse biomass sources. Another key outcome is the strong emphasis on functional material development. Modified polysaccharides and cellulose-derived nanostructures are increasingly used in coatings, packaging systems, and bio-based composites, where they provide improved barrier properties, mechanical reinforcement, and additional functionalities such as antimicrobial activity. In parallel, the incorporation of lignocellulosic fillers into polymer matrices demonstrates clear potential for replacing conventional fossil-based additives in sustainable materials.

Future developments are expected to focus on more selective and low-energy fractionation methods [17], deeper integration of biorefinery chains [18], and the design of high-value multifunctional materials with tailored properties [19].

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References

1. Sundman, O. Absolute Molecular Weight Distribution of Cellulose in DMSO/EmimOAc (1%) with MALS Detection. *Polysaccharides* **2026**, *7*, 47.
2. Stanciu, M.-C.; Tanasă, F.; Teacă, C.-A. Crystallinity Changes in Modified Cellulose Substrates Evidenced by Spectral and X-Ray Diffraction Data. *Polysaccharides* **2025**, *6*, 30. [CrossRef]
3. Podgorbunskikh, E.; Skripkina, T.; Bychkov, A. Mechanical Pretreatment of Plant Biomass: Mechanisms, Energy Efficiency, Technologies, and Life Cycle Assessment. *Polysaccharides* **2026**, *7*, 38. [CrossRef]
4. Puițel, A.C.; Balan, C.D.; Nechita, M.T. Corn Stalks-Derived Hemicellulosic Polysaccharides: Extraction and Purification. *Polysaccharides* **2025**, *6*, 2. [CrossRef]
5. Puițel, A.C.; Balan, C.D.; Nechita, M.T. Comparative Assessment of Edible Oil Plant Lignocellulosic Biomass as Raw Material for a Fiber-Based Integrated Fractionation. *Polysaccharides* **2026**, *7*, 13. [CrossRef]
6. Mohammad Suffian James, R.; Mohd Yusof, N.; Sze Ming, L.; Paik San, H. Biomass-Derived Carbon Fillers in Biopolymer Composite Coating Films for Sustainable Food Packaging: A Review. *J. Compos. Sci.* **2026**, *10*, 296. [CrossRef]
7. Ramdani, A.; Harit, T.; Mokhtari, C.; Malek, F. Elaboration and Characterization of New Polyurethane-Based Biocomposites from Jojoba Oil and Alfa Cellulose Fibers. *Polysaccharides* **2026**, *7*, 9. [CrossRef]
8. Nechita, P.; Iana-Roman, M.; Năstac, S.-M. Acetylated Xylan as Renewable Feedstock for Biodegradable Food Packaging: Synthesis, Structural Characterization and Performance Evaluation. *Polysaccharides* **2025**, *6*, 85. [CrossRef]
9. Camarena-Bononad, P.; Freitas, P.A.V.; González-Martínez, C.; Chiralt, A.; Vargas, M. Influence of the Purification Degree of Cellulose from Posidonia oceanica on the Properties of Cellulose-PLA Composites. *Polysaccharides* **2024**, *5*, 807–822. [CrossRef]
10. Sabo, R.; Schilling, C.; Clemons, C.; Franke, D.; Gribbins, N.R.; Landry, M.; Hoxie, K.; Kitin, P. Grease, Oxygen, and Air Barrier Properties of Cellulose-Coated Copy Paper. *Polysaccharides* **2024**, *5*, 783–806. [CrossRef]
11. Mathel, V.; Rouault, C.; Martin, D.; Halley, P.; Vandi, L.-J. Synergistic effects of PHAs and biomass fillers on the thermal, rheological, and mechanical properties of biocomposites. *Compos. Part A Appl. Sci. Manuf.* **2026**, *202*, 109477.
12. Nakyp, A.; Cherezova, E.; Karaseva, Y.; Akylbekov, N.; Turmanov, R.; Kuandykova, A. Influence of Powdered Lignocellulose from Alfalfa Straw and Its Carboxymethylated Derivative on the Properties of Water-Swelling Rubbers. *Polysaccharides* **2026**, *7*, 16. [CrossRef]
13. Castaño-Rivera, P.; Soto-Arriagada, A.; Ortega, E.T.; Galvez-Garrido, K.; Cabrera-Barjas, G.; Aguilar-Bolados, H.; Castaño, J.; Pereira, M.Á. In Situ Silanization of Ligno-Cellulosic Microfibers Derived from Industrial Waste to Enhance Mechanical Properties of Natural Rubber Compounds. *Polysaccharides* **2025**, *6*, 70. [CrossRef]
14. Vu, H.A.; Le, Q.T.; Nguyen, V.Q. A Direct Preparation of Cellulose Nanocrystals by ZnCl2-Based Deep Eutectic Solvent. *Polysaccharides* **2025**, *6*, 61.
15. Herrera-Balandrano, D.D.; Báez-González, J.G.; Carvajal-Millán, E.; Urías-Orona, V.; Méndez-Zamora, G.; Niño-Medina, G. Feruloylated Arabinoxylans from Nixtamalized Maize Bran By-Product as a Baking Ingredient: Physicochemical, Nutritional, and Functional Properties. *Polysaccharides* **2025**, *6*, 59. [CrossRef]
16. Bandyopadhaya, S.; Bera, D. Feasible and Cost-Effective Approaches for the Conversion of Biomass Wastes into Value-Added Products. In *Conversion and Utilization of Wastes into Sustainable Products*; John Wiley & Sons: Hoboken, NJ, USA, 2026; pp. 567–601.
17. Xu, W.; Zhou, B.; Liu, W. Valorization of waste biomass in the circular bioeconomy: Advances in pretreatment and catalytic conversion technologies in modern biorefineries. *Curr. Opin. Biotechnol.* **2026**, *99*, 103501. [CrossRef] [PubMed]

18. Machin Ferrero, L.M.; Cabrera Jiménez, R.; Wheeler, J.; Pozo, C.; Mele, F.D. An integrated approach to the optimal design of sustainably efficient biorefinery supply chains. *Comput. Chem. Eng.* **2025**, *198*, 109104. [CrossRef]
19. Pandey, S.; Choudhry, S.; Singh, A. Multifunctional Biopolymers. In *Multifunctional Materials*; John Wiley & Sons: Hoboken, NJ, USA, 2025; pp. 393–418.

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