UNIVERZITET U KRAGUJEVCU
AGRONOMSKI FAKULTET U ČAČKU

UNIVERSITY OF KRAGUJEVAC
FACULTY OF AGRONOMY
ČAČAK

1st INTERNATIONAL SYMPOSIUM ON BIOTECHNOLOGY

17–18 March 2023

Faculty of Agronomy in Čačak, University of Kragujevac, Serbia

- PROCEEDINGS -

1st INTERNATIONAL SYMPOSIUM ON BIOTECHNOLOGY

XXVIII Savetovanje o biotehnologiji sa međunarodnim učešćem

- PROCEEDINGS -

ORGANIZER AND PUBLISHER

University of Kragujevac, Serbia
Faculty of Agronomy in Čačak

Technical editors

Prof. Dr Pavle Mašković; Dr Vesna Milovanović; Dušan Marković, BSc

Print-run: 100

Printed by

Copy Xerox, Cara Dušana 11, 32000 Čačak

ISBN 978-86-87611-88-7

Year of publication: **2023**

CONTENTS

Section: Field, Vegetable and Forage Crops

Section: Plant Protection, Food Safety and the Environment

Section: Applied Chemistry

DOI: 10.46793/SBT28.271N

NOVEL TRENDS IN APPLICATION AND PRETREATMENT OF LIGNOCELLULOSIC AGRICULTURAL WASTE

Valentina Nikolić[1], Marijana Simić[1], Slađana Žilić[1], Danka Milovanović[1], Beka Sarić[1], Marko Vasić[1]

Abstract: Lignocellulosic biomass represents the most abundant renewable material in the world, whereas agricultural residues, including those from maize cultivation, comprise a significant fraction of the total plant waste that can be repurposed for various applications. Lignocellulosic feedstocks are non-edible and consist mainly of: cellulose, hemicellulose, and lignin, along with extractive compounds. Pretreatment is required to separate the lignocellulosic biomass into its constituents for efficient utilization. Even after extensive research and development of numerous techniques, pretreatment remains one of the most expensive phases in converting lignocellulosic biomass into biobased products.

Keywords: lignocellulosic biomass, agricultural waste, application, pretreatment.

Introduction

In the last few decades, lignocellulosic biomass has emerged as an increasingly popular for the manufacturing of products with added value. Globally, biomass resources are easily accessible as residual wastes from industrial and agricultural sources. Lignocellulosic biomass may provide numerous possibilities for producing environmentally friendly products (Figure 1), such as biofuels, biochemical, bioplastics and biocomposites for application in the biomedical, pharmaceutical, cosmetics, and other specialty material sectors (Okolie et al., 2021).

Considering lignocellulosic biomass is composed mainly of cellulose, hemicellulose, and lignin and is a component of plant cell walls, it is the prevailing type of biomass in the biosphere (Bayer et al., 2007). Lignocellulosic raw materials can be divided into several groups: 1) agricultural residues (waste from sugar cane, maize, wheat, rice and barley straw, rice husks, olive pits, cotton stalk, etc.); 2) forestry biomass (e.g. wood chips, wood logs, bark,

[1]Maize research Institute, Zemun Polje, Slobodana Bajića 1, Belgrade-Zemun, Serbia (valentinas@mrizp.rs)

sawdust, etc.) originating from both hardwood (aspen, poplar) and soft wood (spruce); 3) energy crops (switchgrass, timothy grass, elephant grass, poplar, willow) 4) cellulosic waste (old newspapers, used office paper, recycled paper pulp, etc.); 5) herbal biomass (alfalfa and other forage plants); and 6) municipal solid waste (Singh et al., 2020; Sanchez and Cardona, 2008).

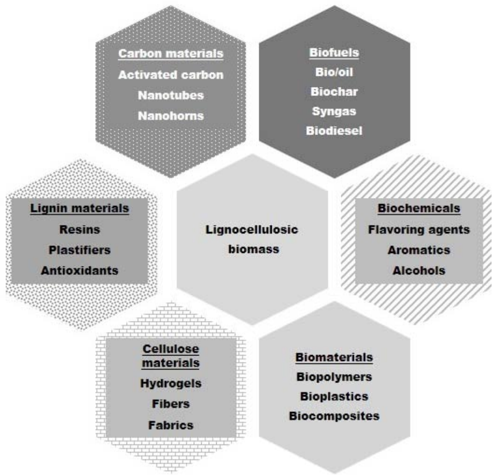

Figure 1. Possible applications of lignocellulosic biomass

Agricultural crop residues, including wheat straw, rice straw, corn cobs and straw, are regarded as significant and plentiful renewable biomass resources (Armah et al., 2020). Interest in maize as a renewable and biodegradable feedstock is increasing in the age of the global energy crisis brought on by the depletion of fossil fuel resources and the rise in environmental pollution. Agricultural waste from the cultivation of maize has a lot of potential for use in the production of bioethanol, highly absorbent water depollutants, bioplastics and other products (Semenčenko et al., 2009).

However, the major obstacle in lignocellulosic biomass conversion to biobased products is the pretreatment of the raw material. For enhancing the biodegradability and digestibility of crop residues, agricultural waste, and other lignocellulosic biomass, novel approaches for pretreatment of biomass may offer ecologically beneficial, economically viable, and sustainable options. The novel methods can be broadly categorized as physical, chemical, biological, physicochemical, and other cutting-edge green solvent-based pretreatment methods.

Composition of lignocellulosic biomass

The basic chemical components of lignocellulosic biomass which make up around 90% of the dry matter are cellulose (35–55 %), hemicellulose (20–40 %), and lignin (10–25 %), respectively.

Cellulose is the main component of the cell wall of higher plants (Okolie et al., 2021). Cellulose fibers ensure the strength of the plant material. When the grids of native cellulose are destroyed, on the primer with strong alkalis or by dissolving cellulose, there is a possibility of its regeneration. The chains of regenerated cellulose are parallel, but thermodynamically more stable than native cellulose (Semenčenko et al., 2011, Sanchez and Cardona 2008).

Hemicelluloses belong to the group of heteropolysaccharides. Softwood and hardwood hemicelluloses, although different in structure and composition hydrolyze to monomer components: glucose, mannose, galactose, xylose, arabinose and small amounts of rhamnose, glucuronic, methyl glucuronic and galacturonic acid. (Mojović et al., 2007). Hemicelluloses are mostly dissolved in alkalis so that they can be more easily hydrolyzed (Sanchez and Cardona, 2008)

Lignin is a very complex molecule composed of phenylpropane units. Wood has a high lignin content. Chemical bonds between lignin and hemicellulose and celluloses are ester, ether and glycosidic. Ether bonds make lignin extremely resistant to chemical and enzymatic decomposition, while biological decomposition is facilitated by many fungi and certain actinomycetes.

Extractives are among the main components of wood materials soluble in neutral organic solvents and water. They consist of a large number of lipophilic and hydrophilic components. Extractives can be classified into four groups: 1) terpenoids and steroids, 2) fats, and waxes, 3) phenolic compounds and 4) inorganic components (Mojović et al., 2007).

Pretreatment methods

Pretreatment procedures are carried out on biomass to overcome the biomaterial's initial resistance to conversion due to their complex physicochemical structure. The processes result in the breakdown of the biomass's components into cellulose, hemicellulose, and lignin (Figure 2). The porosity and surface area of the cellulosic moiety will increase as cellulose decomposes, while the crystallinity will decrease (Semenčenko et al., 2011).

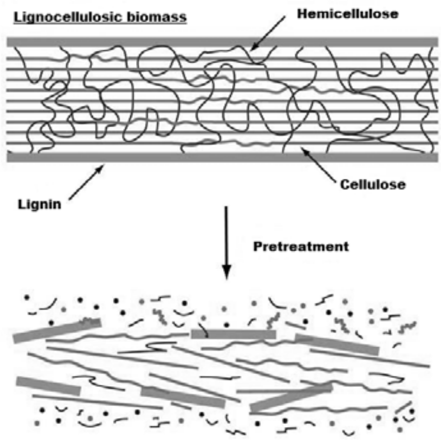

Figure 2. The effect of pretreatment on the lignocellulosic biomass structure

Agricultural waste and other lignocellulosic biomass are pretreated primarily to lower the amount of energy required for conversion, lower the cost, and produce sugars directly from the biomass (Areepak et al., 2022; Zhang et al., 2021). Physical, chemical, biological, physicochemical, and green solvent-based processes are some of the typical pretreatment methods (Awogbemi and Von Kallon, 2022). However, traditional physicochemical methods for removing lignin from lignocellulose feedstocks entail the use and synthesis of a variety of hazardous chemical compounds, some of which can hinder the process itself, as well as considerable energy consumption (Saha et al. 2016). The biological delignification of lignocellulose is an alternative process that is less expensive and safe for the environment. Although biological treatments have clear advantages over conventional ones, they also have certain drawbacks, such as taking longer and being less effective (Ćilerdžić et al., 2022). It is generally recognized that white-rot fungi and their ligninosomes, composed of peroxidases and laccases, are the most promising candidates for the biological pretreatment of lignocellulose. They differ substantially in terms of the method of depolymerizing lignocellulose, i.e., whether they degrade lignocellulose polymers concurrently or only lignin (Saha et al. 2016). According to Knežević et al. (2014), some species have already been confirmed as effective delignifiers of wheat straw, rice straw, oak sawdust, and oil palm wastes, respectively.

Conclusion

Current trends in research regarding the improvement of pretreatment and processing of lignocellulosic biomass, including agricultural residues are closely related to the nature and complex structure of biomaterials. Pretreatment is unavoidable due to the benefits it provides, although adding to the cost, infrastructure needs, labor demands, and energy consumption of the entire production process. Novel methods for pretreatment of biomass may provide environmentally advantageous, financially feasible, and sustainable solutions for improving the biodegradability and digestibility of crop residues, agricultural waste, and other lignocellulosic biomass. Analyzing the possible energy and economic impacts of the pre-treatment process is required to make efficient use of the raw material. Although biological treatments clearly outperform conventional ones, they also have some disadvantages, such as longer treatment times and lower efficacy. Mechanical pretreatment should be reduced, despite the fact that it is frequently necessary, while the chemical pretreatment should be used when processing wood. Using a mix of various approaches is the new strategy to get beyond the drawbacks of pretreatment methods that are carried out as a single operation.

Acknowledgement

This study was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-68/2022-14/200040).

References

Areepak C., Jiradechakorn T., Chuetor S., Phalakornkule C., Sriariyanun M., Raita M., Champreda V., Laosiripojana N. (2022). Improvement of lignocellulosic pretreatment efficiency by combined chemo-Mechanical pretreatment for energy consumption reduction and biofuel production. Renewable Energy, 182, 1094-1102.

Armah E. K., Chetty M., Adedeji J. A., Kukwa D. T. (2020). Valorization of Lignocellulosic and Microalgae Biomass. In *Biotechnological Applications of Biomass*. IntechOpen.

Awogbemi O., Von Kallon D. V. (2022). Pretreatment techniques for agricultural waste. Case Studies in Chemical and Environmental Engineering, 100229.

Bayer E.A., Lamed R., Himmel M. (2007). The potential of cellulases and cellulosomes for cellulosic waste management, Current Opinion in Biotechnology 18, 237-245.

Ćilerdžić J., Galić M., Stajić M. (2022). From pomiculture waste to biotechnological raw material: efficient transformation using ligninosomes and cellulosomes from *Pleurotus* spp. Bioresources and Bioprocessing, 9(1), 66.

Knežević A, Stajić M, Vukojević J, Milovanović I (2014). The efect of trace elements on wheat straw degradation by *Trametes gibbosa*. International Biodeterioration & Biodegradation, 96, 152–156.

Mojović L., Pejin D., Lazić M. (2007). *Bioetanol kao gorivo – stanje i perspektive*, monografija, Tehnološki fakultet, Leskovac.

Okolie J. A., Nanda S., Dalai A. K., & Kozinski J. A. (2021). Chemistry and specialty industrial applications of lignocellulosic biomass. Waste and Biomass Valorization, 12 (5), 2145-2169.

Saha BC, Qureshi N, Gregory J, Kennedy GJ, Michael A, Cotta MA (2016) Biological pretreatment of corn stover with white-rot fungus for improved enzymatic hydrolysis. International Biodeterioration & Biodegradation, 109, 29–35.

Sanchez O. J., Cardona C. A. (2008). Trends in biotechnological production of fuel ethanol from different feedstocks. Bioresource technology, 99 (13), 5270-5295.

Singh A., Nanda S., Berruti F. (2020). A review of thermochemical and biochemical conversion of Miscanthus to biofuels. Biorefinery of alternative resources: targeting green fuels and platform chemicals, 195-220.

Semenčenko V., Mojović L., Petrović S., Ocić O. (2011). Novi trendovi u proizvodnji bioetanola. Hemijska industrija, 65 (2), 103-114.

Semenčenko V., Terzić D., Radosavljević M., Žilić S. (2009). Korišćenje agrorezidua kukuruza u proizvodnji biogoriva, bioapsorbenata i hrane za ljude i životinje. *Book of Proceedings: Industrial waste 2nd International Scientific Conference on Waste Management*, 14-17 September, Tara, Serbia, pp. 209-218.

Zhang R. Y., Liu H. M., Hou J., Yao Y. G., Ma Y. X., Wang X. D. (2021). Cellulose fibers extracted from sesame hull using subcritical water as a pretreatment. Arabian Journal of Chemistry, 14 (6), 103178.