

## Biochemical Extraction and Optimization of Cellulose Fibers from Reeds for Sustainable Applications

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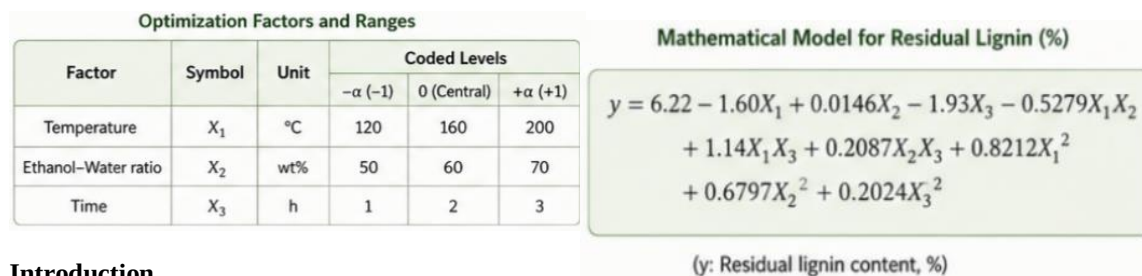
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**Abstract:** This study presents an optimized biochemical process for extracting cellulose fibers from reed biomass (*Phragmites australis*) as a sustainable alternative to synthetic materials. A modified organosolv delignification method was developed and optimized using Response Surface Methodology (RSM) with Central Composite Design (CCD) to evaluate the effects of temperature (120–200 °C), ethanol–water ratio (50–70 wt%), and digestion time (1–3 h) on lignin removal. Optimal conditions (160 °C, 60:40 ethanol–water, 3 h) resulted in residual lignin content of 3% ( $R^2 = 0.9895$ ), experimentally validated with minimal prediction error. Catalytic enhancement with low-concentration sodium hydroxide (0.025 M) further reduced lignin to 0.51% in just 2 h, significantly improving efficiency without compromising cellulose integrity. Comprehensive physicochemical, morphological, and thermal characterizations confirmed that the extracted fibers are suitable for high-value applications in textiles, bio-composites, and bio-based materials. The developed process demonstrates scalability, reduced chemical and energy consumption, and potential integration into circular bioeconomy pathways, which ultimately support the sustainable development of communities

**Keywords:** Cellulose fibers; Reed biomass; Sustainable extraction; Biochemical treatment; Process optimization

### Graphical Abstract



### Introduction

The environmental crisis, driven by plastic pollution and ecosystem degradation, has intensified the search for sustainable alternatives to synthetic materials. Plant-derived natural fibers are promising due to their biodegradability, renewability, and lower environmental impact compared to petroleum-based products [1], [2]. Cellulose, the most abundant biopolymer on Earth, is a key structural component of plant cell walls and underpins applications ranging from paper and textiles to biofuels and advanced biocomposites [3], [4].

Reeds (e.g., *Phragmites australis*, *Arundo donax*) represent a compelling cellulose source. These fast-growing perennials thrive on marginal lands without competition with food crops. Their cellulose content (27.7–46.5%) rivals sugarcane bagasse [5], [6]. Furthermore, their cultivation offers significant

environmental co-benefits, include CO<sub>2</sub> sequestration to total rates of ~31 tons CO<sub>2</sub> ha<sup>-1</sup> yr<sup>-1</sup>, and phytoremediation, making them carbon-negative feedstocks [7]. Valorizing this biomass supports circular economy principles by turning an ecological challenge into a resource opportunity.

Conventional cellulose extraction faces sustainability and efficiency constraints. Mechanical pulping is energy-intensive (2,500–3,000 kWh/ton) and retains high lignin [8], while kraft pulping achieves delignification but suffers cellulose yield losses and creates polluting waste streams [9]. Sulfur-free organosolv methods produce high-purity cellulose (up to 93.2% from *Arundo donax*) but remain limited by solvent recovery costs [10]. Integrated processes, such as subcritical water hydrolysis with pulping and bleaching, have yielded high-quality cellulose with

favorable crystallinity [11]. Further, studies on functionalization-e.g., phosphorylation of reed cellulose nanocrystals—expand potential applications [12].

Optimization of extraction parameters is critical for preserving fiber integrity. Enzyme blends tailored to pretreatments—cellulase-rich for acid-pretreated reeds (~45% conversion) and xylanase-rich for alkaline (~59%)—improve efficiency [13]–[15]. More advanced systems, such as seawater/amine-functionalized ionic liquids, achieve 80.3% delignification and near-complete glucose yield [16]. At scale, integrated reed biorefineries are ~38% more profitable than single-product systems, underscoring the need for optimized fractionation [17].

This study builds on prior work with date palm fronds, where modified organosolv methods and catalyst-assisted delignification enhanced cellulose recovery [18], [19]. We aim to optimize biochemical extraction and bleaching processes, characterize fiber properties, and evaluate their suitability for sustainable applications.

Despite advances, challenges persist in balancing yield, purity, fiber quality, and scalability. Few studies link extraction conditions to fiber performance in biocomposites. This research addresses these gaps by developing environmentally conscious biochemical protocols for reed cellulose extraction, emphasizing reduced chemical use, energy efficiency, and waste minimization. Rigorous characterization will establish structure–property relationships, creating a scalable pathway to convert reed biomass into high-value fibers and reduce reliance on petroleum-based composites.

The objectives are:

1. Develop and optimize a sustainable biochemical /hybrid extraction method for reed cellulose fibers.
2. Characterize physicochemical, morphological, and thermal properties of the fibers.
3. Evaluate their performance as reinforcements in biocomposite formulations.

## Experimental

### Raw Material Collection and Preparation

Reed plants (*Phragmites australis*) was collected from Euphrates River riparian zones (Babylon, Iraq) during March–April 2025. Samples were washed (distilled water  $\times 3$ ), surface-sterilized

with 0.1% NaOCl, air-dried (48 h, 25°C, <10% moisture), chopped (2–5 cm), milled (1 mm sieve), and stored at 4°C. Preparation steps are shown in Fig 1.



Fig. 1: The preparation process of *Phragmites australis*. (a) Harvested whole plants; (b) Stems chopped into segments; (c) Washed leaves.

The chemical compositions of the reed stems and leaves were quantified using standardized protocols, with the results summarized in Table 1.

Table-1: Chemical composition of reed biomass (dry wt.%).

| Component | Weight %, based on (dry basis) |               |        |      |             |
|-----------|--------------------------------|---------------|--------|------|-------------|
|           | Cellulose                      | Hemicellulose | Lignin | Ash  | Extractives |
| Stems     | 40-50                          | 20-30         | 15-25  | 2-6  | 5-10        |
| Leaves    | 27-33                          | 32-38         | 10-14  | 6-12 | 10-12       |

### Ethanol–Water Solution Preparation

Ethanol–water mixtures (50–70 wt%) were prepared at a constant volume of 200 mL by adjusting ethanol mass (96% purity) and completing the volume with distilled water

### Delignification Process- Organosolv Method

This study focuses on improving the extraction of cellulose fibers from reed biomass using a modified organosolv method. The main goal is to obtain high-purity cellulose by adjusting key operating conditions such as temperature, ethanol–water ratio, and reaction time. In addition, a low concentration of NaOH is used to enhance lignin removal and make the process more efficient. Biomass (20 g, 0.17–0.18 mm) was suspended in 200 mL ethanol–water (50–70 wt%), heated (120–200°C, 1–3 h) in a stainless-steel reactor, then filtered and washed. Ethanol solubilized lignin while preserving cellulose. Selected runs used catalysts (NaOH, H<sub>2</sub>SO<sub>4</sub>, Ca(OH)<sub>2</sub>). Process setup is shown in Fig 2.

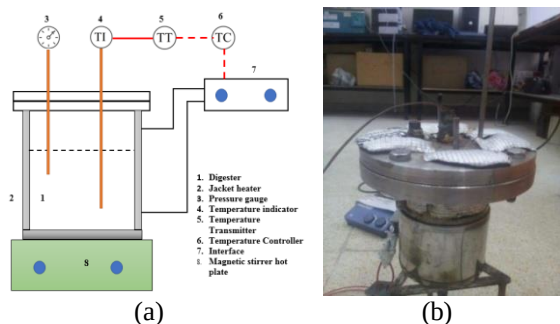


Fig 2: Organosolv setup: (a) schematic; (b) reactor assembly.

### Procedure

Experiments were conducted in a 2-liter batch reactor. Reed biomass (milled to 0.18 mm) was suspended at a ratio of 200 mL solvent per 100 g biomass in an ethanol-water mixture, where ethanol hydrolyzes lignin while preserving cellulose [20]. For catalytic tests, a catalyst was added. The suspension was heated to a target temperature (120–200 °C) under continuous stirring, held for ~60 min, and then cooled. The slurry was filtered, and the solid residue was washed with the ethanol-water mixture and dried at 105 °C. Filtrate samples were retained for UV analysis.

### Washing and filtration of the sample after delignification

Upon completion of the reaction, the treated sample was sequentially washed with a 50:70 ethanol–water solution, followed by multiple rinses with distilled water until the wash liquor transitioned from brown to colorless. The resulting suspension was then filtered under vacuum, as illustrated in Fig 3.



Fig 3: Vacuum filtration during solid-liquid separation.

### Bleaching of Extracted Cellulose

Bleaching was employed as a chemical delignification step to remove residual lignin and produce a whiter cellulose product [21]. The protocol, consistent with established methods from prior work, involved treating the pulp with a sodium chlorite solution followed by sequential washing with alkaline solutions (e.g., 0.15 N NaOH). The efficacy of lignin removal was confirmed by a visible color change from dark brown to white (Fig. 4).

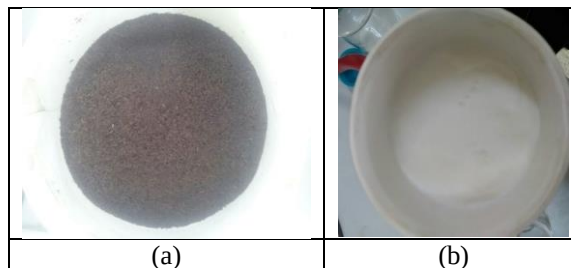


Fig. 4: Cellulose before (a) and after (b) bleaching.

### Lignin Content

Lignin content was quantified following the NREL standard protocol [22]. Briefly, 0.3 g of dried reed biomass (<180 μm) was hydrolyzed with 3 mL of 72% H<sub>2</sub>SO<sub>4</sub> at 30°C for 1 h. The mixture was then diluted with 84 mL distilled water and autoclaved at 125°C for 1 h. The resulting suspension was vacuum-filtered through a pre-weighed crucible, separating acid-insoluble lignin (AIR) and acid-soluble lignin (ASL) fractions. The AIR mass fraction was calculated using Eq. (1).

|                                                                                                                                        |     |
|----------------------------------------------------------------------------------------------------------------------------------------|-----|
| $\text{Air}\% = \frac{\text{Weight}_{\text{crucible plus AIR}} - \text{Weight}_{\text{crucible}}}{\text{ODW}_{\text{sample}}} * 100\%$ | (1) |
|----------------------------------------------------------------------------------------------------------------------------------------|-----|

Where, ODW: oven dry weight which can be calculated using equation (2).

|                                                                                                                                                    |     |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| $\text{ODW} = \frac{\text{Weight}_{\text{sample before dried}} - \text{Weight}_{\text{sample after}}}{\text{Weight}_{\text{sample before dried}}}$ | (2) |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-----|

A 2 mL aliquot of liquor was diluted to 6 mL with distilled water in a pre-dried test tube, and its UV absorbance at 320 nm was recorded [23]. The acid-soluble lignin (ASL) concentration was subsequently calculated using Equation (3).

$$ASL\% = \frac{UV_{abs} * Volume_{filtrate} * Dilution}{\epsilon * ODW_{sample} * Pathlength} * 100\% \quad (3)$$

Where: filtrate volume = 86.73 mL; absorptivity coefficient ( $\epsilon$ ) = 11.4 L·g<sup>-1</sup>·cm<sup>-1</sup> [23]; path length = 1 cm; dilution factor calculated using Eq. (4).

$$Dilution = \frac{Volume_{sample} + Volume_{diluting solvent}}{Volume_{sample}} \quad (4)$$

The total amount of lignin can be calculated using equation (5).

$$\%lignin = \%AIR + \%AS \quad (5)$$

## Results and Discussion

### Optimization of Delignification Parameters

The delignification process was optimized by investigating three key parameters—temperature (120–200°C), ethanol-to-water ratio (50–70 wt%), and digestion time (1.0–3.0 hours)—using a Central Composite Design (CCD). Seventeen experiments were conducted to systematically evaluate variable interactions and maximize data reliability; results are summarized in Table 2.

Temperature exhibited a paramount influence on lignin removal. Increasing temperature from 136°C (Run 1) to 184°C (Run 10) reduced residual lignin content from 12.5% to 5.5%, attributable to enhanced lignin solubility at elevated temperatures. However, no further reduction was

observed at 200°C, indicating a performance plateau beyond 184°C and diminishing returns on energy input.

The ethanol-to-water ratio demonstrated a complex, nonlinear relationship with delignification efficiency. A balanced 60:40 ratio (Runs 3, 11, and 14) yielded moderate lignin removal (6.2–6.3%), while an ethanol-rich 66:34 ratio at 184°C produced optimal results (5.5% residual lignin). In contrast, water-rich conditions (54:46, Run 17) or extended times at low temperatures significantly increased residual lignin (12.5–13%), underscoring the necessity of an optimized solvent composition. Digestion time critically influenced reaction completeness. At 184°C, extending the time from 1.4 to 2.6 hours reduced lignin content from 6.5% to 5.5%. Although a 3-hour digestion at 160°C achieved a lower lignin value (3%), the associated high prediction error (0.55%) suggested experimental variability. Consequently, the optimal balance between efficiency and model reliability was achieved at 184°C, 66:34 ethanol-water ratio, and 2.6 hours digestion time (5.5% lignin, 0.25% error).

Analysis of Variance (ANOVA) confirmed the high statistical significance of the developed second-order polynomial model for lignin content ( $p < 0.0001$ , F-value = 73.01), establishing its robustness. The individual, quadratic, and interaction terms for temperature ( $X_1$ ), ethanol-water ratio ( $X_2$ ), and digestion time ( $X_3$ ) were also assessed for significance. Crucially, a non-significant lack of fit ( $p > 0.05$ ) validated the model's adequacy in representing the experimental data. These statistical findings underscore the reliability of the RSM approach for optimizing the delignification process.

TABLE 2 Experimental design for lignin content (%) in phragmites australis after organosolv delignification

| Run | Temp.<br>°C | Ratio<br>Ethanol: water<br>wt/wt | Time<br>hr | Lignin % Content |       | Percent Absolute<br>Error |
|-----|-------------|----------------------------------|------------|------------------|-------|---------------------------|
|     |             |                                  |            | Exp.             | Pred. |                           |
| 1   | 136         | 54                               | 1.4        | 12.5             | 12.34 | 0.1618                    |
| 2   | 136         | 66                               | 2.6        | 7.5              | 7.23  | 0.2724                    |
| 3   | 160         | 60                               | 2.0        | 6.3              | 6.22  | 0.0771                    |
| 4   | 184         | 54                               | 2.6        | 6.3              | 5.87  | 0.4282                    |
| 5   | 160         | 70                               | 2.0        | 8                | 8.17  | 0.1701                    |
| 6   | 184         | 66                               | 1.4        | 6.5              | 6.39  | 0.1085                    |
| 7   | 120         | 60                               | 2.0        | 11               | 11.23 | 0.2340                    |
| 8   | 160         | 50                               | 2.0        | 7.7              | 8.12  | 0.4209                    |
| 9   | 184         | 54                               | 1.4        | 8                | 7.86  | 0.1380                    |
| 10  | 184         | 66                               | 2.6        | 5.5              | 5.25  | 0.2486                    |
| 11  | 160         | 60                               | 2.0        | 6.3              | 6.22  | 0.0771                    |
| 12  | 136         | 54                               | 2.6        | 6                | 5.70  | 0.3019                    |
| 13  | 160         | 60                               | 3.0        | 3                | 3.55  | 0.5537                    |
| 14  | 160         | 60                               | 2.0        | 6.2              | 6.22  | 0.0229                    |
| 15  | 200         | 60                               | 2.0        | 5.5              | 5.86  | 0.3570                    |
| 16  | 160         | 60                               | 1.0        | 10               | 10.04 | 0.0373                    |
| 17  | 136         | 66                               | 1.4        | 13               | 13.02 | 0.0177                    |

Fig 5 illustrates the strong linear correlation between predicted and actual lignin content values, with data points color-graded from blue (low lignin) to red (high lignin.). The close alignment of points along the 45° diagonal confirms the model's accuracy and reliability across the experimental range. Minimal deviations indicate low prediction error and robust predictive performance.

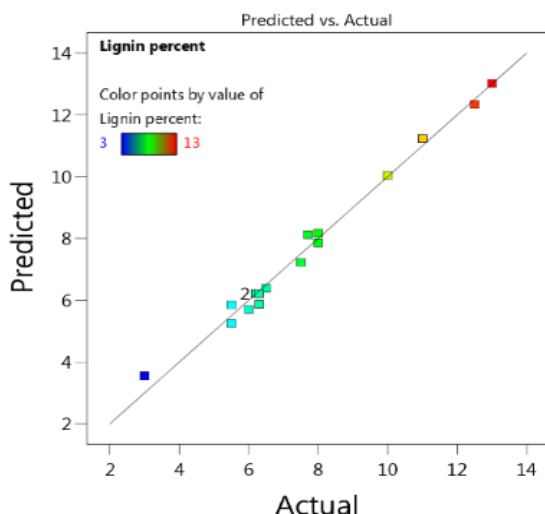


Fig. 5: The Lignin percentage predicted values versus actual values.

#### Mathematical Model and Validation

The effects of temperature, ethanol-water ratio, and digestion time on lignin removal efficiency were systematically investigated using a Central Composite Design (CCD). As a core component of Response Surface Methodology (RSM), CCD efficiently explores variable interactions through factorial, axial, and center points, providing a robust framework for modeling nonlinear relationships and predicting optimal conditions in complex processes like delignification. The relationship between independent variables and lignin content was modeled using a second-order polynomial equation (Equation 6):

$$y = 6.22 - 1.60X_1 + 0.0146X_2 - 1.93X_3 - 0.5279X_1X_2 + 1.14X_1X_3 + 0.2087X_2X_3 + 0.8212X_1^2 + 0.6797X_2^2 + 0.2024X_3^2 \quad (6)$$

where:  $y$  = lignin content (%);  $X_1$  = temperature (°C);  $X_2$  = ethanol-water ratio (wt/wt);  $X_3$  = digestion time (hr).

The equation coefficients quantify variable influences, where negative values for  $X_1$ ,  $X_2$ , and  $X_3$  indicate that increasing temperature, ethanol-water ratio, or digestion time reduces lignin content. The positive  $X_1X_3$  interaction coefficient (temperature and digestion time interaction) reveals a synergistic effect between temperature and time, enhancing delignification beyond their individual contributions.

The model exhibited high reliability with a coefficient of determination ( $R^2$ ) of 0.9895, explaining 98.95% of lignin content variability, and a low standard deviation (4.1%), confirming precise predictive capability. These robust statistical metrics validate the model's suitability for process optimization and industrial scaling, providing a foundation for advanced biomass valorization strategies.

#### Interaction Effects of Process Variables

The contour plots (Figs 4-5) illustrate the interaction effects of temperature, ethanol-water ratio, and digestion time on lignin removal efficiency, highlighting key optimization zones.

Fig 6 (temperature vs. ethanol-water ratio at 1.4 hours) shows inefficient delignification (<13% lignin) at low temperatures (136°C) across all solvent ratios. A distinct optimization zone appears at 184°C with ethanol-rich conditions (66:34 ratio), lowering lignin content to 6.5% (Run 6), demonstrating a clear synergistic effect between higher temperature and increased ethanol concentration.

Fig 7 (temperature vs. digestion time at 60:40 ethanol-water ratio) reveals two key trends. The outlier result of 3% lignin in Run 13 (160 °C, 3 hours) demonstrates high prediction error (0.55%), suggesting experimental variability rather than a reproducible optimum. More reliable data cluster at 6.2-6.3% lignin for 2-hour digestion (Runs 3, 14), with excellent prediction accuracy (<0.08% error). The analysis indicates diminishing returns for digestion times exceeding 2 hours, considering energy efficiency and process economics.

Fig 8 (ethanol-water ratio vs. digestion time at 184°C) clearly defines the process optimization space. Experimental data (Runs 4, 6, 9, 10) validate contour predictions, with Run 10 (66:34 ratio, 2.6 hours) achieving optimal performance (5.5% lignin, 0.25% error). Ethanol-rich conditions (66:34) consistently outperformed balanced (60:40) or water-rich (54:46) mixtures. Digestion times beyond 2.6 hours showed diminishing returns, though the 1.4-2.6 hour window provided operational flexibility with less than 1% lignin variation.

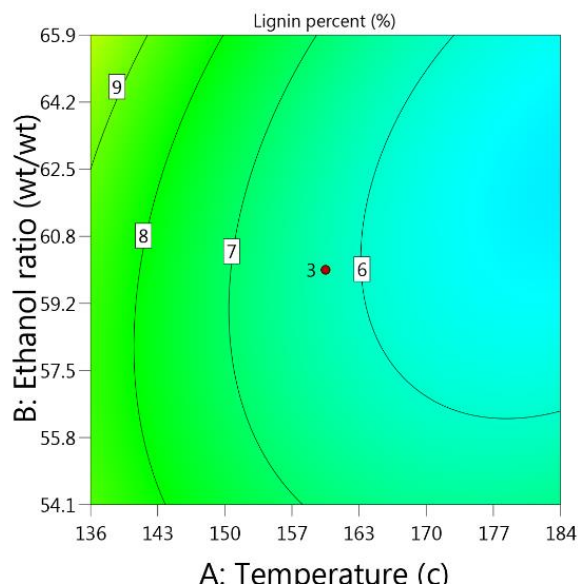


Fig. 6: Effect of temperature and ethanol/ water ratio on lignin percent at fixed digestion time (1.4 hours).

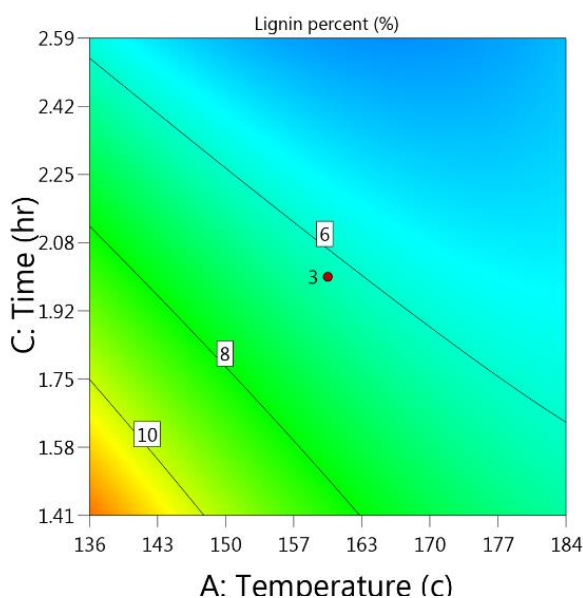


Fig 7: Effect of temperature and digestion time at fixed ethanol/ water ratio (60:40).

The combined analysis of these contour plots and experimental data indicates that while extreme conditions (e.g., Run 13: 160°C, 3 hours) can achieve exceptionally low lignin content (3%), the combination of 184°C, 66:34 ethanol-water ratio, and 2.6 hours (Run 10) represents the most reliable and industrially practical optimum. This condition balances high efficiency (5.5% lignin) with verifiable predictability and operational feasibility.

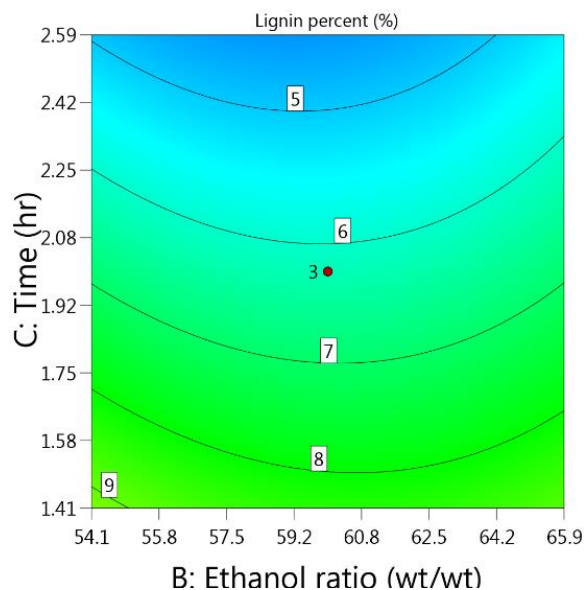


Fig. 8: Effect of ethanol/ water ratio and digestion time at fixed temperature (184 °C.).

Fig 9 explains the temperature-ethanol ratio interaction at a fixed time (2 hours), confirming the consistent superiority of ethanol-rich conditions (~66 wt%), particularly above 163°C where lignin content drops below 6%. The 95% confidence bands validate robust performance enhancement within the 170–184°C range, demonstrating effective synergy between elevated temperature and ethanol-dominant solvents for optimal delignification efficiency.

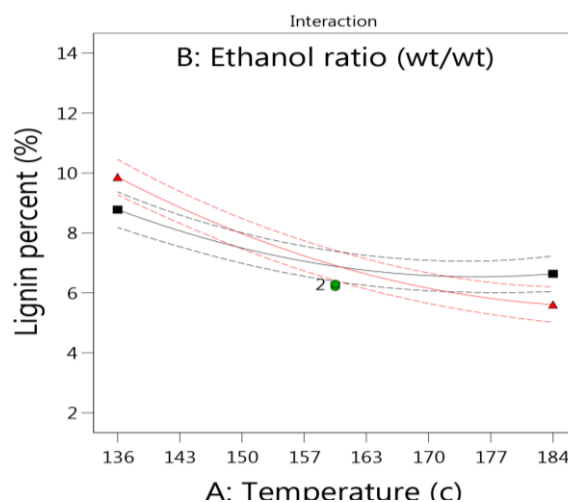


Fig. 9: Lignin content as a function of temperature and ethanol fraction at fixed time (2 h), including 95% confidence bands.

### Catalytic Enhancement of Delignification

Catalysts markedly enhanced organosolv delignification efficiency, reducing reaction time and improving lignin removal. Three catalysts—sodium hydroxide (NaOH), sulfuric acid ( $\text{H}_2\text{SO}_4$ ), and calcium hydroxide ( $\text{Ca}(\text{OH})_2$ )—were evaluated at low concentrations (0.025 M for NaOH and  $\text{H}_2\text{SO}_4$ ; 0.05 M for  $\text{Ca}(\text{OH})_2$ ) to determine their effects on delignification kinetics and efficacy.

NaOH proved most effective among the catalysts tested, reducing residual lignin to 0.51% within just 2 hours—significantly faster than the 3 hours required without catalyst. This accelerated delignification demonstrates NaOH's dual mechanism: enhancing lignin solubilization while reducing cellulose polymerization, thereby preserving fiber integrity. This depolymerization effect is particularly advantageous for downstream applications such as rayon production.

In contrast,  $\text{H}_2\text{SO}_4$  and  $\text{Ca}(\text{OH})_2$  demonstrated inferior performance, yielding residual lignin of 5–6%.  $\text{H}_2\text{SO}_4$  promoted non-selective hemicellulose degradation, potentially compromising cellulose integrity, while  $\text{Ca}(\text{OH})_2$  exhibited insufficient alkalinity for effective delignification, as shown in Fig 10. The strategic use of low catalyst concentrations (0.025 M for NaOH/ $\text{H}_2\text{SO}_4$ ; 0.05 M for  $\text{Ca}(\text{OH})_2$ ) minimized operational costs, reduced corrosion risks, and enhanced environmental sustainability, aligning with green chemistry principles for scalable industrial applications.

### Conclusions

This research demonstrates that *Phragmites australis* reeds, often underutilized or considered invasive, can be transformed into high-quality cellulose fibers using an optimized biochemical extraction method. Key findings include:

1. Optimal delignification conditions of 160 °C, 66:34 ethanol–water ratio, and 3 h yielded 3% residual lignin with high predictive accuracy ( $R^2 = 0.9895$ ).
2. Catalytic enhancement with NaOH (0.025 M) accelerated lignin removal to 0.51% within 2 h, outperforming other catalysts.
3. The process combines energy efficiency, minimal chemical use, and environmental sustainability while producing cellulose suitable for biocomposites, textiles, and bioethanol applications, which ultimately supports the sustainable development of communities.

Future work should focus on catalyst recovery, solvent recycling, and life-cycle assessments to ensure economic and environmental viability at industrial scale.

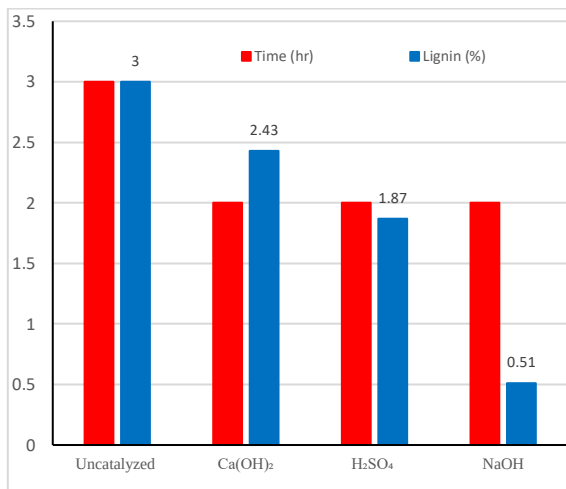


Fig. 10: Effect of different catalysts (NaOH,  $\text{H}_2\text{SO}_4$ ,  $\text{Ca}(\text{OH})_2$ ) on lignin removal efficiency and delignification time compared to uncatalyzed process.

### References

1. I. Ghanmi, F. Slimani, S. Ghanmi and M. Guedri, Development and Characterization of a PLA Biocomposite Reinforced with Date Palm Fibers, Eng. Technol. Appl. Sci. Res., 14, 13631 (2024). <https://doi.org/10.48084/etasr.6988>
2. P. Hait, R. Karthik, R. Mitra and R. Halder, Natural and Artificial Fibre Reinforced Concrete: A State-of-art Review, Int. J. Eng., 37, 503 (2024). <https://doi.org/10.5829/ije.2024.37.03c.07>
3. A. Babaei-Ghazvini, B. Vafakish, R. Patel, K. J. Falua, M. J. Dunlop and B. Acharya, Cellulose Nanocrystals in the Development of Biodegradable Materials: A Review on CNC Resources, Modification, and Their Hybridization, Int. J. Biol. Macromol., 258, 128834 (2024). <https://doi.org/10.1016/j.ijbiomac.2023.128834>
4. H. Harahap, R. Nawansyah, H. Nasution, T. Taslim and I. Iriany, Isolation and Characterization of Nanocrystal from Corncob Waste Using  $\text{H}_2\text{SO}_4$  Hydrolysis Method, Int. J. Eng., 31, 533 (2018). <https://doi.org/10.5829/ije.2018.31.04a.03>
5. Y. Chen, D. Yang, W. Tang, C. Ma and Y.-C. He, Improved Enzymatic Saccharification of Bulrush

- via an Efficient Combination Pretreatment, *Bioresour. Technol.*, 385, 129369 (2023). <https://doi.org/10.1016/j.biortech.2023.129369>
6. D. Doreswamy, A. S. Madival, R. Sony and S. K. Bhat, Physico-Mechanical Characterization of Recycled Waste Tire Rubber and Rice Straw Reinforced Composite, *Int. J. Eng.*, 37, 2021 (2024). <https://doi.org/10.5829/IJE.2024.37.10A.13>
  7. H. Paulapuro, *Mechanical Pulping*, 1st Ed., Fapet Oy, Jyväskylä, Finland (2000).
  8. G. Henriksson, U. Germgård and M. E. Lindström, A Review on Chemical Mechanisms of Kraft Pulping, *Nord. Pulp Pap. Res. J.*, 39, 297 (2024). <https://doi.org/10.1515/npprj-2023-0015>
  9. A. A. Shatalov and H. Pereira, High-grade Sulfur-free Cellulose Fibers by Pre-hydrolysis and Ethanol-alkali Delignification of Giant Reed (*Arundo donax* L.) Stems, *Ind. Crops Prod.*, 43, 623 (2013). <https://doi.org/10.1016/j.indcrop.2012.08.003>
  10. F. Pattnaik, S. Nanda, V. Kumar, S. Naik and A. K. Dalai, Isolation of Cellulose Fibers from Wetland Reed Grass Through an Integrated Subcritical Water Hydrolysis-Pulping-Bleaching Process, *Fuel*, 311, 122618 (2022). <https://doi.org/10.1016/j.fuel.2021.122618>
  11. A. Ait Benhamou, Z. Kassab, M. Nadifiyine, M. H. Salim, H. Sehaqui, A. Moubarik and M. El Achaby, Extraction, Characterization and Chemical Functionalization of Phosphorylated Cellulose Derivatives from Giant Reed Plant, *Cellulose*, 28, 4625 (2021). <https://doi.org/10.1007/s10570-021-03842-6>
  12. R. S. Abolare, S. Jaiswal and A. K. Jaiswal, Green and Sustainable Pretreatment Methods for Cellulose Extraction from Lignocellulosic Biomass and Its Applications: A Review, *Carbohydr. Polym. Technol. Appl.*, 7, 100396 (2024). <https://doi.org/10.1016/j.carpta.2023.100396>
  13. E. Balaguer Moya, B. Syhler, J. Ordeñana Manso, G. Dragone and S. I. Mussatto, Enzymatic Hydrolysis Cocktail Optimization for the Intensification of Sugar Extraction from Sugarcane Bagasse, *Int. J. Biol. Macromol.*, 242, 125051 (2023). <https://doi.org/10.1016/j.ijbiomac.2023.125051>
  14. M. V. Semenova, A. M. Rozhkova, D. O. Osipov, V. D. Telitsin, E. A. Rubtsova, E. G. Kondrat'eva, I. S. Vasil'eva, O. V. Morozova, A. I. Yaropolov and A. P. Sinitsyn, Methods for Preprocessing Reeds to Obtain Enzymatic Hydrolysates with a High Sugar Content, *Appl. Biochem. Microbiol.*, 60, 931 (2024). <https://doi.org/10.1134/S0003683824604736>
  15. M. Jiao, J. Lu, J. Hu, J. Du, Y. Lv, J. Hu, Y. Tao and H. Wang, Optimizing Combinatorial Pretreatment for Efficient Separation and Utilization of Reed Components, *Ind. Crops Prod.*, 222, 119665 (2024). <https://doi.org/10.1016/j.indcrop.2024.119665>
  16. B. Pereira, W. F. Marcondes, W. Carvalho and V. Arantes, High Yield Biorefinery Products from Sugarcane Bagasse: Prebiotic Xylooligosaccharides, Cellulosic Ethanol, Cellulose Nanofibrils and Lignin Nanoparticles, *Bioresour. Technol.*, 342, 125970 (2021). <https://doi.org/10.1016/j.biortech.2021.125970>
  17. Y. S. Mahdi, A. H. Mohammed and A. K. Mohammed, Delignification of Date Palm Fronds Using Modified Organosolv Technique, *Al-Khwarizmi Eng. J.*, 13, 1 (2017). <https://doi.org/10.22153/kej.2017.07.001>
  18. B. Atanasova, T. De Saegher, L. I. Garbarino, I. Stals, J. Vercammen, A. Verberckmoes, J. De Clercq, J. Thybaut and J. Lauwaert, Navigating Process Optimization in Organosolv Fractionation: A Model-driven Approach Applied to Poplar Biomass, *Sep. Purif. Technol.*, 377, 134221 (2025). <https://doi.org/10.1016/j.seppur.2025.134221>
  19. S. Susi, M. Ainuri, W. Wagiman and M. A. F. Falah, Effect of Delignification and Bleaching Stages on Cellulose Purity of Oil Palm Empty Fruit Bunches, *IOP Conf. Ser.: Earth Environ. Sci.*, 1116, 012018 (2022). <https://doi.org/10.1088/1755-1315/1116/1/012018>
  20. J. Ruwoldt, M. Tanase-Opedal and K. Syverud, Ultraviolet Spectrophotometry of Lignin Revisited: Exploring Solvents with Low Harmfulness, Lignin Purity, Hansen Solubility Parameter, and Determination of Phenolic Hydroxyl Groups, *ACS Omega*, 7, 46371 (2022). <https://doi.org/10.1021/acsomega.2c04982>
  21. B. Atanasova, T. De Saegher, L. I. Garbarino, I. Stals, J. Vercammen, A. Verberckmoes, J. De Clercq, J. Thybaut and J. Lauwaert, Navigating Process Optimization in Organosolv Fractionation: A Model-driven Approach Applied to Poplar Biomass, *Sep. Purif. Technol.*, 377, 134221 (2025). <https://doi.org/10.1016/j.seppur.2025.134221>