Publications

LIST OF PUBLICATIONS

Thesis work publications

1. **Baruah, J.**, Nath, B. K., Sharma, R., Kumar, S., Deka, R. C., Baruah, D. C., and Kalita, E. Recent trends in the pretreatment of lignocellulosic biomass for value-added products. *Frontiers in Energy Research*, 6:141, 2018.

2. **Baruah, J.**, Deka, R. C., and Kalita, E. Greener production of microcrystalline cellulose (MCC) from *Saccharum spontaneum* (Kans grass): Statistical optimization. *International Journal of Biological Macromolecules*, 154:672-682, 2020.

3. **Baruah, J.**, Bardhan, P., Mukherjee, A. K., Deka, R. C., Mandal, M., and Kalita, E. Integrated pretreatment of banana agrowastes: Structural characterization and enhancement of enzymatic hydrolysis of cellulose obtained from banana peduncle. *International Journal of Biological Macromolecules*, 201:298-307, 2022.

Thesis work publications under preparation

1. **Baruah, J.**, Gaur, N. K., Dowerah, D., Bardhan, P., Mandal, M., Poddar, M. K., Deka, R. C., and Kalita, E. Catalytic transformation of biomass-derived glucose into 5-hydroxymethylfurfural through magnetically recoverable polyaniline-based bifunctional solid-acid catalyst: An experimental and computational study.

2. **Baruah, J.**, Gaur, N. K., Biswakarma, N., Bardhan, P., Mandal, M., Poddar, M. K., Deka, R. C., and Kalita, E. Design of acid bifunctionality (Lewis and Brønsted) on mesoporous silicate, KIT-6 for the conversion of biomass-derived glucose into 5-hydroxymethylfurfural.
3. **Baruah, J.**, Bardhan, P., Deka, R. C., Mandal, M., and Kalita, E. Comparison of RSM, ANN and ANFIS for Enzymatic Hydrolysis of Cellulose Extracted from *Saccharum spontaneum* for 5-HMF production

Other publications

1. Chaliha, C., **Baruah, J.**, and Kalita, E. Nanoarchitectonics of Crosslinked Cu: ZnS-Lignocellulose Nanocomposite: A Potent Antifungal and Antisporulant System Against

the Tea Pathogen Exobasidium vexans. *Journal of Inorganic and Organometallic Polymers and Materials,* 32(3):954-966, 2022.

2. Bardhan, P., **Baruah, J.**, Raj, G. B., Kalita, E., and Mandal, M. Optimization of culture conditions for biomass and lipid production by oleaginous fungus *Penicillium citrinum* PKB20 using response surface methodology (RSM). *Biocatalysis and Agricultural Biotechnology,* 37:102169, 2021.
3. **Baruah, J.**, Chaliha, C., Nath, B. K., and Kalita, E. Enhancing arsenic sequestration on ameliorated waste molasses nanoadsorbents using response surface methodology and machine-learning frameworks. *Environmental Science and Pollution Research,* 28(9):11369-11383, 2021.
4. **Baruah, J.**, Chaliha, C., Kalita, E., Nath, B. K., Field, R. A., and Deb, P. Modelling and optimization of factors influencing adsorptive performance of agrowaste-derived Nanocellulose Iron Oxide Nanobiocomposites during remediation of Arsenic contaminated groundwater. *International Journal of Biological Macromolecules,* 164:53-65, 2020.

5. Deka, R. C., Deka, A., Deka, P., Saikia, S., **Baruah, J.**, and Sarma, P. J. Recent advances in nanoarchitectonics of SnO_2 clusters and their applications in catalysis. *Journal of Nanoscience and Nanotechnology*, 20(8):5153-5161, 2020.

Book chapters

1. Kalita, E., and **Baruah, J.** Environmental remediation. In *Colloidal Metal Oxide Nanoparticles,* pages 525-576. Elsevier, 2020.

2. Das, P., **Baruah, J.**, and Kalita, E. Recent Developments in the Enzymatic and Biocatalytic Pretreatment of Microalgae for Efficient Biofuel Production. *Micro-algae: Next-generation Feedstock for Biorefineries*, pages 193-210. Springer Nature Singapore, 2022.

3. Dutta, L., **Baruah, J.**, and Kalita, E. Biorefinery Approach for Sustainable Biodiesel and Bioethanol Production from Microalgae. In *Micro-algae: Next-generation Feedstock for Biorefineries,* pages 31-53. Springer Nature Singapore, 2022.

4. **Baruah, J.,** Chaliha, C., Kalita, E. Nanobioremediation: Innovative Technologies for Sustainable Remediation of Environmental Contaminants. In *Agricultural and*

Environmental Nanotechnology: Novel Technologies and their Ecological Impact, pages 463-486. Springer Nature Singapore, 2023.

CONFERENCES AND SYMPOSIUMS ATTENDED

Conference proceedings:

1. Poster presentation on "*Optimization and Characterization of nanocelluloses extracted from Saccharum spontaneum"* during International Conference **IJBS-2017** held on February 1-4, 2018 at Indian Institute of Technology, Guwahati, Assam.
2. Poster presentation on *"Extraction and characterization of hemicellulose and cellulose nanofibers from Kans grass (Saccharum spontaneum)"* during International Conference **ORGANIX-2018** held on Dec 20-21st, 2018 at Tezpur University, Tezpur, Assam.
3. Oral presentation on "*Optimization and Characterization of Microcrystalline Cellulose extracted from Banana Cob"* during National Symposium on Sustainable Waste Management (**NSSWM 2019**) held on Aug 3rd, 2019 at Tezpur University, Tezpur, Assam.
4. Poster presentation on "*Preparation and characterization of cellulose fibers from banana peel via an eco-friendly approach*" during International E-conference on Physics of Materials and Nanotechnology **(ICPN-2021)** held on Oct 28th, 2021 Mangalore University, Mangalore, Karnataka.

5. Poster presentation on "*Isolation and characterization of cellulose microfibers from banana pseudostem using an integrated approach*" during International E-conference on Physics of Materials and Nanotechnology **(ICPN-2021)** held on Oct 29th, 2021 Mangalore University, Mangalore, Karnataka.

6. Poster presentation on "*Efficient conversion of banana peduncle derived glucose into 5-Hydroxymethylfurfural using a Sulfonated Polyaniline Based* Fe_3O_4 *catalyst*" during **RSC Chemical biology symposium** held on May 9th, 2022.

Workshops attended:

1. DST sponsored National Workshop on "**Green Chemistry- Its Opportunity and Challenges, Preventing Pollution at Molecular Level**" on 26-27 Nov. 2010 organized by Department of Chemistry, D.R. College, Golaghat, Assam.
2. JEOL sponsored workshop on **"Nuclear Magnetic Resonance (NMR)"** Oct 13th, 2017 organized by JEOL India pvt, ltd. In collaboration with Tezpur University, Tezpur, Assam.
3. UGC SAP DRS-II sponsored workshop on **"Powder X-Ray Diffraction"** on March 14- 15, 2019 organized by Department of Chemical Sciences, Tezpur University, Tezpur, Assam.

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Recent Trends in the Pretreatment of Lignocellulosic Biomass for Value-Added Products

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Lignocellulosic biomass (LCB) is the most abundantly available bioresource amounting to about a global yield of up to 1. 3 billion tons per year. The hydrolysis of LCB results in the release of various reducing sugars which are highly valued in the production of biofuels such as bioethanol and biogas, various organic acids, phenols, and aldehydes. The majority of LCB is composed of biological polymers such as cellulose, hemicellulose, and lignin, which are strongly associated with each other by covalent and hydrogen bonds thus forming a highly recalcitrant structure. The presence of lignin renders the bio-polymeric structure highly resistant to solubilization thereby inhibiting the hydrolysis of cellulose and hemicellulose which presents a significant challenge for the isolation of the respective bio-polymeric components. This has led to extensive research in the development of various pretreatment techniques utilizing various physical, chemical, physicochemical, and biological approaches which are specifically tailored toward the source biomaterial and its application. The objective of this review is to discuss the various pretreatment strategies currently in use and provide an overview of their utilization for the isolation of high-value bio-polymeric components. The article further discusses the advantages and disadvantages of the various pretreatment methodologies as well as addresses the role of various key factors that are likely to have a significant impact on the pretreatment and digestibility of LCB.

Keywords: lignocellulosic biomass, pretreatment, hydrolysis, enzymatic breakdown, cellulose extraction, delignification, biorefinery

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INTRODUCTION

The population of the world is projected to reach 8.5 billion by 2030 and 9.7 billion in 2050. Commensurate with the increasing population, the global energy consumption is expected to rise from 575 British thermal units (BTU), as estimated in 2015, to about 736 quadrillion BTU in 2040, which is a 28% increase over a period of 25 years (EIA, 2017). The global dependence on non-renewable fossil fuels for meeting the current energy needs, cannot be sustained for long in the face of the depleting fuel reserves. The effects of this excessive dependence are already evident in the escalation of fuel prices, over the past decade and the severe environmental impacts like climate change. With a mere 23.7% utilization of renewable energy sources for energy needs, it is vital that world switches over to renewable and sustainable energy alternatives, on an urgent

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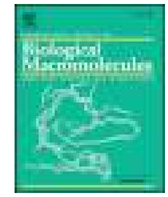

Greener production of microcrystalline cellulose (MCC) from *Saccharum spontaneum* (Kans grass): Statistical optimization

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ABSTRACT

In this study, microcrystalline cellulose (MCC) was isolated from *Saccharum spontaneum* by integrating alkaline delignification, chlorine-free bleaching, and acid hydrolysis treatments, through an environment friendly and sustainable method. To minimize acid concentrations, the acid hydrolysis conditions were optimized using Taguchi orthogonal L_9 design that evaluated the influences of reaction time, temperature, acid concentration and solution to pulp ratio on the physical and chemical characteristics of MCC. The cellulose source at its different stages of processing was submitted to various analytical techniques for morphological and physiochemical investigations. The highest MCC yield optimized was 83%. This process is favorable due to the use of very low (5% H_2SO_4) acid concentration, low corrosivity, effluent reduction, and cost-effectiveness. Detailed analyses showed that the isolated MCC has good crystallinity and thermal stability and hence expected as a high-value precursor for the production of polymer biocomposites for diverse applications.

1. Introduction

Saccharum spontaneum (*S. spontaneum*), also known as Kans grass is a perennial herbaceous plant belonging to the *Poaceae* family that grows rapidly on non-agricultural lands alongside the roads, canals and river banks. The grass does not hold much commercial value presently and is widely distributed in Asia, the Mediterranean regions and the warm temperate regions of Africa [1]. *S. spontaneum* has been reported to contain 45.10 ± 0.35% of cellulose and 22.75 ± 0.28% hemicellulose on the dry solid basis [2]. Due to its high cellulosic and hemicellulosic content it has become popular as a renewable bioresource for the production of second-generation ethanol [3–5] and preparation of green polymer composites [6–8]. Although, one recent report has demonstrated the potential industrial application of *S. spontaneum*, where it was used for the isolation of chlorine-free bleached pulp for the paper industry, the isolation of high-value cellulosic products like Microcrystalline cellulose (MCC) remains unexplored [9]. Microcrystalline celluloses (MCC) are in fact partially depolymerized celluloses, conventionally derived from diverse α-cellulosic precursors through the treatment of mineral acids for reducing the degree of polymerization [10]. During such processes, the amorphous cellulosic contents are removed leaving the MCC with a characteristically high degree of crystallinity, ranging from 55% to 80%. In addition, the MCC possess unique mechanical and physiochemical features including renewability, biodegradability, non-toxicity, high mechanical properties, low density, large surface area, biocompatibility, and good hygroscopicity [11]. As such, MCC has been used as binders and fillers in pharmaceutical industries, as thickeners, stabilizers, emulsifiers and gelling agents in food industries, as water retainers and viscosity regulators in ointments and lotions and as a reinforcing agent in the preparation of polymer composites [11–13]. Wood and cotton are, the major industrial sources for cellulosic fibers and are therefore the most important feedstocks used in MCC development [14–16]. However, with depleting forest resources and the increasing scarcity of conventional precursors for MCC production, the focus in the recent years have shifted towards other readily available, economical alternatives like rice husk [17], pomelo peel [18], oil palm empty fruit bunch [19], bamboo [20], cotton wool [21], jute [22], soybean hulls [23], fodder grass [13], Alfa grass fibers [24], tea waste [25], etc. In this context, non-woody plants and grasses which have lower constituent lignin content are seen to be more economical for MCC production, as they are less demanding in terms chemical treatments and energy inputs [13,24].

The MCC extraction from lignocellulosic materials firstly involves the elimination of lignin and hemicelluloses followed by isolation of the crystalline cellulosic fibers. Conventionally, delignification is carried out using the alkaline treatment to disrupt the lignin structure and enable the separation of the structural linkages between lignin and carbohydrates. The delignified fibers are then subjected to bleaching treatment to obtain the cellulose fibers which usually

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Integrated pretreatment of banana agrowastes: Structural characterization and enhancement of enzymatic hydrolysis of cellulose obtained from banana peduncle

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ABSTRACT

An integrated treatment coupling alkali, steam explosion and ammonia/chlorine-free bleaching with sequential mild acid pretreatment were performed to isolate and characterize cellulose from banana agrowastes followed by optimized enzymatic hydrolysis to glucose. The cellulose yield, compositional, microstructural, and morphological analysis initially obtained from three post-harvest banana agrowastes (peel, pseudostem, and peduncle) were surveyed. Isolation parameters for banana peduncle agrowastes, the most efficient precursor, were reconfigured for acid hydrolysis by applying an orthogonal L_9 array of Taguchi design. Effects of solution-to-pulp ratio, acid concentration, temperature, and reaction time on physicochemical parameters were assessed resulting in ~81% cellulose recovery. Subsequently, cellulase driven enzymatic conversion to glucose was modelled using response surface methodology (RSM), where the mutual influences of incubation time, enzyme concentration, substrate concentration, and surfactant concentration were investigated. Artificial Neural Network (ANN) modelling further improved upon RSM optimizations ensuing ~97% optimized glucose yield, verified experimentally.

1. Introduction

Conversion of underutilized agricultural biomass resources into value-added products, such as biofuels and platform chemicals, is a sustainable recourse for repurposing agricultural crop residues towards industrial valorisation. The main components of agricultural biomass residues are cellulose, hemicellulose and lignin, where cellulose and hemicellulose fractions are sugar polymers, making them a potential source of sugars viz., glucose and xylose [1]. Banana agrowastes despite being one of the most abundant lignocellulosic sources remains underutilized [2]. Bananas are widely cultivated in Asia, Latin America, and Africa with an annual production of over 116 million metric tonnes (MMT) globally and account for 16% of the total global food production. India is currently the highest producer with 27.9 MMT, followed by China, (10.1 MMT), and the Philippines (7.8 MMT) [3]. Consequently, the agrowastes generated thereof (banana peduncle, peels, leaves, and pseudostems) accumulate in enormous quantities, whereas it could serve as a viable lignocellulosic feedstock [4].

Glucose is a necessary sugar that serves as a platform component for producing chemicals, biofuels, and materials using chemical and biological methods [5]. Glucose is traditionally derived from starch, however, given the current food shortage globally, the quest for non-food sugar sources is significant and intriguing [6]. Cellulose, an alternate source for glucose production is an abundant polymer of β 1,4-glycosidic bond linked glucose units that can be hydrolysed either chemically or enzymatically. Enzymatic hydrolysis is preferred since it is gentle, extremely selective and prevents the formation of inhibitors for downstream enzymatic conversions [7]. Given that celluloses in lignocellulosic agrowaste are imperviously interwoven within matrices of hemicelluloses and lignin, enzymatic hydrolysis mandates pretreatments for reorganising the inter-and intramolecular hydrogen bond network, the shape of cellulose, as well as lignin removal [8]. Some

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