



REVIEW ON EXTRACTION OF CELLULOSIC FIBER FROM THE DEAD LEAVES OF PEEPAL TREE

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Abstract: The paper is a review on the extraction processes of cellulosic fibers from fallen dead leaves. The two lignocellulosic crops have a long history of use by humans for extraction of the bast fibers among other purposes. The utility of bast fibers declined over time with industrial advances and changes to the economy, but of late, with an increase of focus on environmental impact and sustainability, there is a renewed interest in these resources. The use of biomass-based resource requires an appreciation of plant anatomy and the agronomical variables in their cultivation and harvesting. This review provides an overview of these aspects as well as of the processes of retting for initial weakening of the plant structure in preparation for fiber extraction, degumming to isolate fiber bundles, and delignification.

Keywords: Cellulose, Fibers, *Calathea lutea*, acid hydrolysis, FTIR, XRD.

I. INTRODUCTION

The synthesis of plant organic matter, including leaf, stem, and root tissues, is always influenced by environmental variables. Therefore, the structural components of cell walls carry the information concerning conditions prevailing when the cellulose was formed, reflecting local and regional environmental conditions [1], ecological impacts, and potential disturbances e.g., forest management or massive pest infestation damage. Although the biochemical processes of cellulose biosynthesis are generally well understood however the inter-annual variability of different metabolic pathways still requires in-depth investigations, especially regarding the differences between species and between plant tissues. Considering that the first place where all the fundamental biochemical processes occur from organic compounds, such as cellulose is the leaf, the investigation of leaf tissues is extremely worthwhile. In particular, when considering that the first important isotope fractionations of hydrogen, oxygen, and carbon undergo on the leaf level [2– 5].

II. RESEARCH MOTIVATION

Cellulose is the most abundant biopolymer on the biosphere and is recognized as the major component of biomass (wood, agricultural plants, and residues), bacteria, algae, and tunicin. It is the fibrillar component of biomass cell walls, and essentially a linear condensation polymer consisting of Danhydro glucopyranose units joined together by β (1→4) glycosidic bonds. Cellulose continues to attract considerable attention for more than 150 years as a popular biomass resource material. It continues to remain an indispensable raw material for paper, food, textile, pharmaceutical, energy, and composite industries. The major source of cellulose is wood and its consumption is continuously increasing worldwide and even in countries where wood resources are limited. The rational and innovative utilization of agricultural residues or nonwood (plant fibers) biomass as new sources of cellulose is of potential interest worldwide. Agricultural crops/forestry residue and plant fibers offer several environmental benefits owing to their renewable nature, abundance, low cost, low energy consumption in production, etc. Cellulose is the main component of several plant fibers and agricultural crops residue such as bamboo, cotton, flax, hemp, jute, sisal, banana, and straws (rice and wheat). Generally, the natural fibers mainly consist of cellulose, hemicellulose, and lignin and then cellulose is separated from the noncellulosic substances using mechanical and chemical methods. Many studies were conducted on the extraction of cellulose from biomass for producing pulp, paper, and reinforced plastics. The present research work is aimed at the extraction of cellulose from ficus leaves by using the chemical approach. Ficus tree leaves are of forestry residues (nonwood) in the tropical region.

III. LITERATURE REVIEW

Fahmida-E- Karim et al. [1] Riding on the journey of a sustainable world it is very crucial to extend the usage of natural cellulosic fiber from renewable sources. Due to their numerous applications and eco-friendly behavior, natural cellulosic fibers are in greater demand every day. In this article a new natural fiber extracted from the creepers of *Mikania micrantha* with the help of 5% NaOH

retting process. Previously no research work have been done with this fiber. The fiber was characterized by following ASTM D1909, ASTM D 2654, ASTM D1445, TAPPI standard for determination of moisture regain and content, bundle fiber strength and chemical composition respectively. XRD, SEM, FTIR and TGA analysis were also done for the identification of crystallinity, fiber morphology, functional group and thermal behavior. The tests results showed that it is a cellulose enriched textile fiber having 56.42% cellulose. The average moisture regain and content % were 9.17% and 8.4% respectively analyzed from the five samples. The average tenacity was determined 38.6 gm/tex with 1.8% elongation and the crystallinity of the tested fiber was 72%. The maximum degradation temperature for this fiber was 477 °C. The application of this noble fiber can be for making fiber reinforced composites, cellulose nanomaterials, biomaterials etc.

Xin Zhang et al. [2] The environmental and efficiently extracted cellulose technology with a high α -cellulose content from agricultural waste hemp stalks were treated by prepared Pectin Lyase (PL) and trace chemical additives. This extraction technique can obtain different α -cellulose content to meet the conditions for preparing pulp (PPs), viscose fibers (VFs) and nanofibrillated cellulose (CNFs). Specifically, fermentation process of PL (temperature, time, rotation rate and centrifugation rate) was evaluated on the reductive sugar concentration, fungus concentration and activity of hydrolase and lyase. Additionally, the morphological structure, chemical structure, crystallization structure, intermolecular action, and technical indicators of PPs, VFs and CNFs were characterized. The optimal results of fermenting PL were 10.3 U/mL of lyase activity and 36.1 U/mL of hydrolase activity. The technical indicators of PPs were 14.30 N·m/g of the horizontal ring pressure and 64 of the horizontal fold resistance times; The technical indicators of VFs were 2.13 cN/dtex of the intensity and 19.36% of the elongation at break; The length and width of CNFs were 326 nm and 3 nm, respectively.

Benhamadouche Lamia et al. [3] Researchers and industry are looking for green and sustainable materials as reinforcement for lightweight composite structures. This research aim was designed to study the characteristics of the fibre extracted from a waste product of the spathe of date palm (SDP). In this work, density, crystallinity index, crystal size, tensile strength, surface roughness, extreme degradation temperature and thermal stability of SDP fibres were investigated. Density is estimated to be 0.59 g/cm³. X-ray diffraction analysis indicated the crystallinity index about (57.82%) and the crystal size is (19 nm). The results of the thermal analysis gave the degradation temperature as 270 °C and E_a as 69.14 kJ/mol. Scanning electron microscopy (SEM) investigation confirmed the presence of surface contaminants including wax and other foreign materials. Also, the mechanical properties identified are tensile strength (100 ± 21.5 MPa), and Young's modulus ($4 \pm 0.9\%$ GPa). Based on the study's findings, SDP fibres should be considered for usage as a reinforcing material in the development of novel polymer composites with a wide range of lightweight industrial applications.

Zhangyun Chen et al. [4] The effect of beating starting pulp was investigated on the oxidation efficiency of ammonium persulfate (APS), the yield, and the properties of the CNCs. The beaten pulp and the subsequent CNCs were characterized, respectively, by different techniques. The CNCs were classified as CNC1 and CNC2, dependent on ultrasonication. It showed that the beating exposed more free OH groups in the pulp and enhanced the yield and surface charges of CNCs. Compared to the CNC2, the CNC1 had a higher surface charge, higher crystallinity, higher thermal stability, shorter length, smaller length distribution, and slightly larger width. The CNC1 and CNC2 had similar rheological properties. For the beaten pulp with a beating degree of 25°SR, the yields of the CNC1 and the total CNCs reached the maximum, 42.65 and 34.11 %, respectively. The surface charges of the CNC1 and the CNC2 also reached the maximum, -44.5 and -33.6 mV, respectively. Their crystallinity indexes were 80.07 and 75.42 %, respectively. The lengths of the CNC1 and the CNC2 were 157.31 ± 30.61 and 214.92 ± 65.52 nm, and their widths were 10.13 ± 2.74 and 9.43 ± 2.99 nm, respectively. Therefore, proper beating enhanced the APS oxidation efficiency and influenced the CNCs properties.

Caroliny Santos et al. [5] Cellulose fiber extraction occurs via the action of microorganisms in a process known as retting, which is widely used to extract fibers such as flax. Extraction requires the presence of microorganisms in a plant soaked for a period that varies according to the plant species. Retting can result in new cellulose fibers that are a sustainable alternative to their polluting chemical counterparts, which are sources of microplastics. As such, the present study aimed to study the microbiological retting technique used to extract fibers from papaya stems. The fiber yield was evaluated as well as fiber properties, and thus, the best fiber from the papaya stem was determined. Three different regions of the stem were considered for fiber extraction for comparison purposes. After extraction, papaya stem fibers were characterized by optical microscopy, field-emission gun scanning electron microscopy (FESEM), density, wettability, X-ray diffraction, breaking strain, and tensile strength. The results showed that removing the bark and pulp from the papaya stem improves process yield. In addition, papaya fibers have different characteristics and properties depending on the region of the stem.

Lalita Chopra, Manikanika et al. [6] Cellulosic fiber or cellulosic biomass finds major role in the modern scientific era. The cellulosic fibers were well utilized in today's research due to the unique properties of cellulose such as its biocompatibility, biodegradability, non-toxic etc. Nature is the major sources of cellulose along with some minor sources such as microbial cellulose (fungal, bacterial, algal etc.). One of the major research areas today is to extract cellulose from natural resources abundant with us such as rice husk, wheat husk, maize husk, pine needles, cotton, jute etc. Cellulose can be extract from these available sources by numerous chemicals, mechanical and green techniques. Cellulose extraction can be carried out at nano, micro or macro scale by the processes like alkalization, bleaching, acidic hydrolysis etc. Extracted cellulosic fiber was analyzed by different analysis techniques such as X-Ray Diffraction (XRD), Fourier transform infra-red (FTIR) etc. The present review article represents the importance of the waste biomass to be a useful resource for the extraction of cellulose.

Gloria I. Ngene et al. [7] In this study, we investigated the influence of hemicelluloses removal treatment on the reactivity of the resulting pulp. The idea was to develop treatment strategies consisting of mechanical refining (different refining technologies), chemical treatment (CCE), and xylanase treatment that enabled both quantitative xylan removal as well as good reactivity to dissolution without the need for additional post-extraction treatments (cellulose activation) to improve reactivity. Cellulose post-extraction treatments result in additional production costs. The reactivity of the extracted pulps was evaluated based on the degree of

swelling in NaOH and dilute cupriethylene diamine solution (CUEN), the solubility in 8% NaOH at -10 °C, and the Fock reactivity. The result obtained showed that hemicelluloses removal strategies that included mechanical refining treatment led to better pulp reactivity than unrefined pulp. The best result was obtained with refined pulp extracted with 6% soda (cellulose II not detected). In addition, we obtained a Fock reactivity ranging from 60 to 70%. The good correlations found between fiber swelling, solubility in caustic soda, and Fock reactivity suggest that the tedious Fock test could be substituted by the much simpler swelling and solubility measurements. The negative impact of cellulose II on pulp reactivity is due to the higher number of hydrogen bonds formed under dewatering and drying. This problem would most likely be averted in the ideal case where pulp dissolution is integrated into the pulp mill.

Nadiah Syafiqah Mohd Azlan et al. [8] Cellulose is a valuable resource for organic synthesis owing to its low cost, abundance, and sustainability. However, crystalline cellulose in lignocellulosic biomass is frequently smothered by the recalcitrant amorphous layers of lignin and hemicellulose that limit its extractability. Therefore, this study aimed to find the best solvent to combine with a microwave-assisted method for fast and efficient extraction of cellulose from oil palm mesocarp fiber. Results showed that γ -valerolactone gave the highest average cellulose yield (64.0%), followed by protic solvents viz. 2-butoxyethanol (62.8%) and ethyl lactate (57.3%), however, there was no statistical difference ($p > 0.05$) between the three solvents. Crystalline cellulose in biomass seems to interact with aprotic solvent via dipole–dipole interactions slightly more efficiently than with protic solvent via hydrogen bonds. However, as an aprotic solvent, ethyl acetate showed an exception low cellulose yield (50.7%), presumably due to its boiling point which is lower than the operating temperature. Among all, ILs ([BMIM][Cl], [HMIM][HSO₄] and [EMIM][Ac]) performed the poorest giving only 36.0% to 52.0% of cellulose yields. The mixture of [HMIM][HSO₄]/ γ -valerolactone (1:1, v/v) performed similar to the sole [HMIM][HSO₄]. Overall, the combination of γ -valerolactone and microwave extraction allowed a high yield of cellulose to be achieved within a short period of 2 min, at a relatively low temperature of 140 °C, although faint hydrolysis into glucose was detected. The cellulose extracted from γ -valerolactone showed a higher crystallinity index (46.81%) than raw biomass (24.06%), indicating a high purity product and the removal of amorphous portion.

Singam Suranjoy et al. [9] Singh Ultrasound-assisted alkali urea (UAAU) pre-treatment of miscanthus biomass was investigated for enhanced delignification and extraction of cellulose fiber. The effects of pre-treatment conditions investigated were: sonication time (10.0, 15.0 and 20.0 min), alkali (NaOH) concentration (2.0, 3.5 and 5.0 %, w/v) and urea-concentration (1.0, 1.75 and 2.5 %, w/v) on the delignification and cellulose content. The process parameters were studied and optimized using a response surface methodology (RSM) based on the Box Behnken Design (BBD). From the RSM-BBD analysis, the optimized pre-treatment conditions were 2.1 % NaOH, 1.7 % urea and 15.5-min sonication time with maximal cellulose and lignin contents of 47.8 % (w/w) and 27.5 % (w/w) respectively. The pre-treated samples were further characterized by FTIR, colorimeter, SEM, XRD, and TGA analyses. The UAAU pretreated samples have higher delignification and cellulose contents than the AU pre-treatment without sonication. Furthermore, the ultrasound process allowed selective removal of lignin without substantially degrading the functionalities of cellulose fiber. The UAAU pre-treated samples exhibited higher thermal stability, fibrillation, crystallinity index and smaller crystallite size.

Deeksha Jaiswal et al. [10] Nowadays, as environmental awareness is a key issue among researchers, scientific community is looking for natural materials as they are biodegradable, low cost, eco-friendly and also safe for health. Researchers and academicians have found many natural fibers and studied their properties for their sustainable applications in various possible sectors, and studies are also going on. So, in that context several natural fibers like jute, sisal, banana, pineapple, flax, hemp, kenaf, bamboo, cornstalk waste, coir, etc. have been successfully utilized as a reinforcing material in polymer composites by replacing man-made synthetic fiber. Apart from traditional natural fibers, scientific community is also looking for locally available natural fibers across the globe in different geographical locations for successful reinforcement in polymer matrix. This will not only decrease the burden on traditional fibers but also at the same time it would be helpful to enrich the rural economy. Natural fiber-based composites can be used in different areas such as automotive industry, construction industry, sports industry and food industry. This study is related with extraction, characterization, surface treatment, thermal analysis and activation energy of different uncommon natural fibers available at different geographical locations worldwide. The purpose of this study is to provide a comprehensive knowledge on extraction techniques, treatment methodologies, and properties of these uncommon natural fibers so that these novel materials can be utilized efficiently as a reinforcing material in different polymer matrix. Discussions on traditional natural fibers like Bagasse, Wheat straw, Coir, Pineapple, Banana etc. have been compiled extensively in various review papers but compilation on these new uncommon natural fibers is rare. Thermal analysis along with activation energy evaluation is another aspect which has been given emphasis in discussion because this is also a very important examination to evaluate the thermal stability of these natural fibers.

Aiqin Gao et al. [11] Cellulose nanocrystals (CNC) was successfully extracted from natural *Calotropis gigantea* fiber (CGF) by a combined ball milling defibrillation and SO₄²⁻/TiO₂ nano-solid superacid catalyst-assisted method. In the extraction process, natural *Calotropis gigantea* fibers were defibrillated layer by layer, subsequently, catalysis degraded by nano-solid superacid catalysis. The new extraction method avoids large amounts of acid pollution. The yield of CNC obtained from *Calotropis gigantea* fiber was 55.37 %. Rod-like CNC with an average length of 242.06 nm and width of 8.80 nm was obtained. The aspect ratio of the CNC (the length:width) was 27.5 times. The green method avoids the use of large amounts of sulfuric acid. The ball milling defibrillation combined with SO₄²⁻/TiO₂ nano-solid superacid catalyst-assisted provides an efficient and sustainable manner to make full use of natural *Calotropis gigantea* fiber resources.

Ying Wang et al. [12] Uranium extraction from seawater is considered as an efficient strategy to meet the increasing demands of uranium. Amidoxime has been reported as one of the most efficient groups for uranium affinity. Herein, amidoximated cellulose fibers were synthesized by grafting polyacrylonitrile (PAN) onto cellulose fibers followed by amidoxime modification. The amidoximated cellulose fibers showed maximum adsorption capacity of 52.88 mg g⁻¹ (pH = 5.0), and its static adsorption process was well fitted with Langmuir model and Pseudo-second-order kinetics. The adsorption mechanism was attributed to the chelating reaction between uranyl complexes and amidoximated cellulose fibers. The prepared fibers were further fabricated into nonwoven

membrane for dynamic adsorption, and the breakthrough curves were well fitted to Dose-Response model. The amidoximated cellulose fiber membrane showed a good adsorption capacity of 1.22 mg g⁻¹ at pH 8.0 after filtrating 10.0 L simulated seawater, demonstrating promising efficient engineering materials for uranium extraction from seawater.

Xiaoshuai Han et al. [13] Natural fibers are an ideal choice for fabricating advanced functional materials. In this study, novel ultrastrong and tough natural cellulosic fiber bundles (RFs) extracted from vascular tissues of manau rattan stems were obtained. The physical, mechanical, chemical, thermal, crystallographic, and morphological characteristics of RFs with different diameters were analyzed. The chemical composition analysis showed that more cellulose and less lignin existed in thinner RFs. Scanning electron microscopic images revealed that manau rattan was mainly composed of vascular bundles, consisting of xylem, parenchyma, and runthrough thicker tracheids. X-ray diffraction analysis indicated the RFS had higher crystallinity (51.7 %) than RFM (49.7 %) and RFL (47.7 %). The rattan fiber bundles showed simultaneously enhanced tensile strength (170.2 for RFS vs. 65.6 MPa for RFL) and toughness (31.6 for RFS vs. 16.7 MJ/m³ for RFL) as diameter decreased. Tensile strength and toughness were 482.6 MPa and 79.9 MJ/m³ when RF diameter decreased to 0.15 mm. These findings suggested that these RFs will play a promising role in the field of nanoadvanced functional materials.

Lobna A. Elseify et al. [14] Novel long fibrillated date palm fibers were extracted from the midribs using alkaline treatment. The midribs were treated at different conditions by varying three parameters; NaOH concentration, treatment duration, and treatment temperature. The average crosssectional area was measured using cork method. Single fiber tensile test was used to determine the fiber dry and wet tensile strength and modulus of elasticity. Increasing the extent of the alkaline treatment resulted in a significant removal of the non-load bearing amorphous constituents and hollow content, this was associated with a significant fibrillation resulting in an initial increase in strength which then dropped as the severity kept increasing. Moreover, it was noticed that the highest dry tensile strength (452.79 MPa) was obtained when the fibers were treated at high temperature (100°C) with low NaOH % (1%) and vice versa. Wet tensile test showed a significant reduction in strength compared to the dry results, which is due to the significant reduction in the load sharing efficiency. The extracted fibers had better properties than the fibers extracted from the date palm midribs in the literature, the fibers were 98% longer and 80% stronger. Date palm midrib fibers show a very promising future in replacing and competing with other natural fibers especially in the reinforcement of composites.

Sangeeta Sankhla et al. [15] This study aims to assess Na₂CO₃ treatment as a potential pre-treatment for extracting cellulose micro-fibers and subsequently cellulose nanofibrils (CNF) from sugarcane bagasse. For cellulose microfibrils extraction, Na₂CO₃ concentration, reaction time, and temperature were critical factors influencing reaction kinetics. It was concluded from statistical analysis of crystallinity index (CrI) that temperature was the most significant factor. Moreover, reaction time and Na₂CO₃ concentration were minimized while maximizing temperature to get an increase of 33 % and 115.2 % in the CrI and activation energy of thermal degradation, respectively. FTIR analysis of cellulose micro-fibers indicated the removal of hemicellulose and lignin. For the preparation of CNF, ionic liquid (IL) 1-n-butyl-3-methylimidazolium chloride was used. The CNF diameter was in the range of 4–35 nm, and the length was in a few micrometers. Hence Na₂CO₃ treatment in the combination of IL treatment is an efficient and environmentally friendly approach to valorize sugarcane bagasse into high-value CNF.

IV. EXTRACTION OF CELLULOSE FIBERS

Appropriate natural fiber extraction represents a major test faced during processing of plant fibers. Extraction methods to separate plant fibers include retting and mechanical extraction processes [3,4]. Common retting methods are water, dew, chemical, and enzyme retting [5,6]. Water retting is the most common method to extract high-quality fibers. In the retting process, existence of bacteria and moisture in the plants allows them to break down large parts from cellular tissues and adhesive substances that surround fibers, enabling separation of individual fibers from the plant. Depending on the fiber category, this process requires approximately 7 to 14 days [7,8]. Water retting is critical to processing of fibers; it influences qualities of generated fibers, and retting quality is a primary issue for industries that use natural fibers in their products [7]. Therefore, reaction time must be carefully evaluated when water retting is used, because under- or excessive retting can cause difficulties in separation of individual fibers, or may weaken fiber strength [9].

Cellulose is the most prevalent substance on the planet and the major component of plant-cell walls. The principal components of plant fibers include cellulose, hemicellulose, lignin, pectin, and wax [1,2]. However, cellulose is dependent on plant type and the geographical area in which it is cultivated [3]. As a result, suggests development of novel cellulose-based materials and demands detailed examination of their physical and chemical properties [4]. In this context, there has been a surge in interest in extracting cellulose from natural fibers in recent years. Several experiments have been conducted, utilizing natural fibers, including sisal, rice husk, sugarcane bagasse, cotton, hemp, jute, bamboo, and kenaf, among others, as sources of cellulose [3,5,6,7].

Extraction processes and methods for extracting cellulose vary and may include acid and alkaline media; each process yields unique properties for each type of cellulose produced. Because amount of cellulose and extraction process vary from plant to plant, it is crucial to note that cellulose tests and investigations are carried out separately [3]. The purpose of the extraction process is to obtain cellulose with a high yield and purity through elimination of non-cellulosic components—mainly extractives, hemicellulose, and lignin—using different solvents with various concentrations, reaction temperatures, and times for each step of extraction. This allows for extraction-process variable adjustments that lead to optimization strategies [3]. Therefore, in this study, the retting-time duration endpoint and influence of rettingtime duration on fibers' physical, tensile, and thermal properties were investigated. Chemical compositions of fiber retted at optimal water-retting duration were analyzed, and cellulose was extracted and characterized using optimized multistep celluloseextraction-process parameters.

V. CONCLUSION

This investigation presents a method for obtaining cellulose fibers from fallen leaves using various Author methods. The aim of this article is to investigate the possibility of using fallen leaves as an alternative source of cellulose. The relevance of research lies in the disposal of waste raw materials in the form of fallen leaves, which are an annual multi-tonnage raw material.

REFERENCES

- [1]. Karim, F. E., Islam, M. R., Ahmed, R., Siddique, A. B., & Begum, H. A. (2023). Extraction and characterization of a newly developed cellulose enriched sustainable natural fiber from the epidermis of *Mikania micrantha*. *Heliyon*.
- [2]. Zhang, X., Guo, J., Yu, Y., Hao, X., Xu, Y., Yao, Q., & Guo, Y. (2023). Preparation of Pectin Lyase by fermentation for customized extraction of paper pulp, viscose fiber, and nanofibrillated cellulose from hemp stalks. *Industrial Crops and Products*, 203, 117137.
- [3]. Lamia, B., Nafissa, M., Djoubair, B. A., Jawaid, M., Fouad, H., & Midani, M. (2023). New cellulosic fibre from Spathes of male date for lightweight composite materials: extraction and characterization. *Journal of Materials Research and Technology*, 24, 5361-5371.
- [4]. Chen, Z., Xie, Z., & Jiang, H. (2023). Extraction of the cellulose nanocrystals via ammonium persulfate oxidation of beaten cellulose fibers. *Carbohydrate Polymers*, 121129.
- [5]. Santos, C., Santos, T., Aquino, M., & Alves, S. (2023). Extraction and characterization of cellulosic fibers from the stem of papaya tree (*Carica papaya* L.). In *Cellulose Fibre Reinforced Composites* (pp. 243-265). Woodhead Publishing.
- [6]. Chopra, L. (2022). Extraction of cellulosic fibers from the natural resources: a short review. *Materials Today: Proceedings*, 48, 1265-1270.
- [7]. Ngene, G. I., Roux, J. C., & Lachenal, D. (2022). Xylan extraction strategies and the performance of the resulting high purity cellulose fiber to swelling and dissolution. *Carbohydrate Polymer Technologies and Applications*, 3, 100196.
- [8]. Azlan, N. S. M., Yap, C. L., Gan, S., & Rahman, M. B. A. (2022). Effectiveness of various solvents in the microwaveassisted extraction of cellulose from oil palm mesocarp fiber. *Materials Today: Proceedings*, 59, 583590.
- [9]. Singh, S. S., Lim, L. T., & Manickavasagan, A. (2020). Ultrasound-assisted alkali-urea pre-treatment of *Miscanthus giganteus* for enhanced extraction of cellulose fiber. *Carbohydrate polymers*, 247, 116758.
- [10]. Jaiswal, D., Devnani, G. L., Rajeshkumar, G., Sanjay, M. R., & Siengchin, S. (2022). Review on extraction, characterization, surface treatment and thermal degradation analysis of new cellulosic fibers as sustainable reinforcement in polymer composites. *Current Research in Green and Sustainable Chemistry*, 5, 100271.
- [11]. Gao, A., Chen, H., Tang, J., Xie, K., & Hou, A. (2020). Efficient extraction of cellulose nanocrystals from waste *Calotropis gigantea* fiber by SO₄²⁻/TiO₂ nano-solid superacid catalyst combined with ball milling exfoliation. *Industrial crops and products*, 152, 112524.
- [12]. Wang, Y., Zhang, Y., Li, Q., Li, Y., Cao, L., & Li, W. (2020). Amidoximated cellulose fiber membrane for uranium extraction from simulated seawater. *Carbohydrate polymers*, 245, 116627.
- [13]. Han, X., Ding, L., Tian, Z., Wu, W., & Jiang, S. (2021). Extraction and characterization of novel ultrastrong and tough natural cellulosic fiber bundles from manau rattan (*Calamus manan*). *Industrial Crops and Products*, 173, 114103.
- [14]. Elseify, L. A., Midani, M., Hamouda, T., Khiari, R., & Hassanin, A. H. (2023). Extraction of cellulosic fibers from date palm by-products. In *Extraction of Natural Products from Agro-Industrial Wastes* (pp. 261-280). Elsevier.
- [15]. Sankhla, S., Sardar, H. H., & Neogi, S. (2021). Greener extraction of highly crystalline and thermally stable cellulose micro-fibers from sugarcane bagasse for cellulose nano-fibrils preparation. *Carbohydrate polymers*, 251, 117030.