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ISOLATION AND CHARACTERIZATION OF CELLULOSE DERIVED FROM PROMINENT AGRICULTURAL WASTE (SUGARCANE BAGASSE) AND ITS UTILIZATION IN VARIOUS BIOMEDICAL FIELD

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ABSTRACT
Background: Agricultural waste clearance and reutilization is a significant problem today. Objective: Successful extraction and purification of cellulose and its derivatives (methylcellulose) from agri-waste and pollution. This is an innovative polymer (cellulose & its derivatives) that can be used in pharmaceutical and technical applications in an eco-friendly manner**. Aim:** Isolate and characterize cellulose derived from prominent agricultural waste (sugarcane *bagasse*) and its utilization in various biomedical fields. **Method:** Eco-friendly Soxhlet extraction utilizing organic solvents was employed to give a high yield of cellulose. Further, the obtained cellulose was bleached and transformed into ester derivatives, such as methylcellulose, to analyze their properties. **Result:** This study's primary goal is to concentrate on the production of cellulose and its extraction from different agricultural waste & its characterization. The cellulose isolated from different biomass was comparatively evaluated for its varied properties and was found suitable for use in the pharmaceutical industry or technical dimensions. **Conclusion:** Agri waste has significant potential and sources for value-based products. Here, successful extraction and derivatization of the cellulose from the sugarcane were done. These extracted celluloses were further subjected to various pharmacopeial, micromeritics, and physiochemical properties assessments, including advanced characterization to evaluate and validate the properties of the products, which signifies more efficient, green extraction and pharmacopeial utilization.

INTRODUCTION

Agricultural biomass has the peerless potential for conversion into energy and other evaluated products. Different types of biomass, with their origin and organization, are illustrated in Figure 1. In many developing countries, like India, the primary agricultural waste sources include sugarcane bagasse, peanut shells, rice husks, coffee husks, maize husks, and paddy straw [1]. Agricultural biomass refers to material from living things,

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including plants, animals, maize, straw, offal, and perennial grasses. The sustainability of this biomass and its pollution management can be achieved with the active use of the latest scientific developments and trans-disciplinary technology [2]. The ecology faces difficulties due to our nation's inadequate agricultural waste handling. It is possible to create valuable products by utilizing the potential advantages of agricultural waste. Finding efficient methods to transform these wastes into useful chemicals or materials is urgently needed. Various compounds have been extracted from crop wastes, including carbohydrates, minerals, proteins, and other molecules [3]. To preserve the environment and make advantage of the natural positive energy present in such feedstocks, alternative methods for processing the enormous amount of surplus agricultural leftovers, such as sugarcane bagasse, must be developed [4].

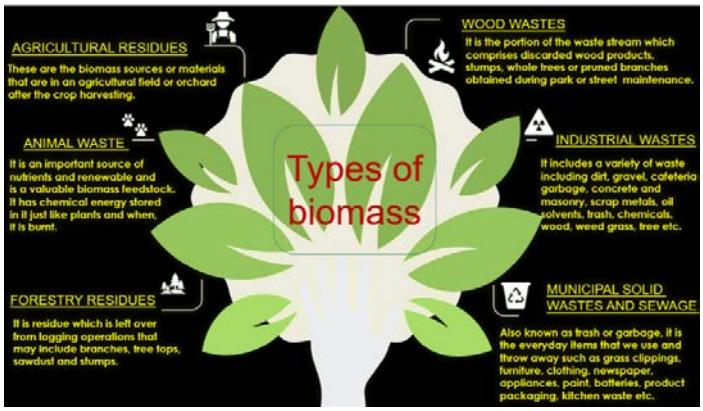

Figure 1: Biomass types with their introduction/ classification

Sugarcane (*Saccharum officinarum* L.), a tall perennial grass belonging to the Poaceae family, ranks among the leading crops globally, mainly grown for its stalks that are rich in sugar. Beyond its primary role in sugar production, sugarcane has significant medicinal properties, including anti-inflammatory, antioxidant, and immunomodulatory effects, attributed to its rich composition of polyphenols, flavonoids, and other bioactive compounds [5]. After the juice extraction from sugarcane stalks, the remaining fibrous residue, known as bagasse, constitutes approximately 30% of the crushed sugarcane biomass. Sugarcane bagasse is predominantly composed of cellulose (40-45%), hemicellulose (25-30%), and lignin (20-25%), making it a valuable lignocellulosic resource for various industrial applications [6].

Cellulose is a sustainable resource and the most prevalent organic polymer. Its importance is increasing in various aspects. Cellulose with a molecular formula $(C_6H_{10}O_5)_n$, representing a polysaccharide composed of a linear sequence of several hundred to thousands of β (1-4) linked D-glucose units. Its chains are produced and assembled within plant cells, forming highly organized fibrillar structures with lateral diameters ranging from 2 to 20 nm and crystallinities between 65% and 95%. Plant cell walls are primarily composed of cellulose, hemicellulose, and lignin, which account for their great strength [7]. Cellulose is the most predominant polymer in biomass; the cellulose composition is illustrated in Figure 2.

Mechanical disintegration, enzymatic digestion, oxidation, and acid hydrolysis can be used to extract cellulose fibrils from various materials, the two primary sources being cotton and wood pulp. The overuse of fossil fuels has led to resource scarcity and climatic disruption on a worldwide scale. The growing global population and rising energy consumption have made it necessary to investigate sustainable energy sources [8]. The primary component of plant biomass, cellulose, is widely available and does not compete with the availability of food [9]. It is estimated that 70–95% of this amount is composed of lignocellulose, which includes 40–50 % w/w cellulose. As a result, cellulose is seen as a sustainable fossil fuel substitute. Plant cell walls comprise cellulose, hemicellulose, and lignin, which account for their great strength. In addition to mechanical disintegration, enzymatic digestion, oxidation, and acid hydrolysis can extract cellulose fibrils from various materials, the two main sources being cotton and wood pulp [10]. One potential remedy for the energy dilemma and global warming is biomass-based renewable energy, like cellulosic ethanol. The main cellulosic ethanol sources are grass, crop wastes, and biomass from forestry. The primary component of plant biomass, cellulose, is widely available and does not compete with the availability of food [11]. Cellulose ethers and cellulose esters are the two derivatives of cellulose. Their mechanical and physicochemical characteristics differ [12].

Polymeric materials have a wide range of applications in pharmaceutical formulations. These materials are valuable in liquid dosage forms for stabilizing and thickening, granules and tablets for binding, and semisolid preparations for gelling. Additionally, they are utilized in medicinal adhesive patches, free-flowing agents, flavor masking, and fillers. Transdermal patches are commonly employed in topical, cosmetic, and transdermal drug delivery systems [13, 14]. These substances,

cellulose derived from various biomass and its derivatives, have significant uses in different pharmaceutical applications, including osmotic drug delivery systems, bioadhesives and mucoadhesives, and compression tablets for improving compressibility [15]. These polymeric materials can also be employed as medicinal adhesive patches, free-flowing agents, flavor maskers, and fillers [16].

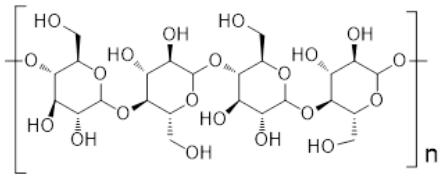

Figure 2: Structure of the cellulose

The research topic focuses on the reutilisation of agricultural waste, which is considered a burden that causes various ecological and environmental calamities. Our research emphasizes the utilization of agricultural waste like sugarcane bagasse as a source for extracting the reasonable quality of cellulose and its derivatives, thus reducing the burden on conventional sources of cellulose like plants and trees. So, tackling a few of the many problems like agriculture waste management by utilizing the waste as a potential source for excipients and creating alternative sources for obtaining pharmaceutical grade excipients, thus reducing the utilization of the plants and the trees, contributing to reforestation. The current study aims to extract and isolate cellulose from agricultural waste biomasses, such as sugarcane bagasse. The extracted cellulose will then be characterized and pharmaceutically evaluated using a range of physiochemical and pharmacopoeial parameters, including Optical microscopy, SEM, FTIR, DSC, etc.

MATERIALS AND METHODS

NaOH-Sodium hydroxide (Fisher Scientific), $Ca(ClO)_2$ - Calcium Hypochlorite (HiMedia), H_2O_2-Hydrogen peroxide (Rankem), were used as chemicals, and $C_6H_5CH_3$ -Toluene, C_2H_5OH-Ethanol, C_3H_6O-Acetone (Rankem) and demineralized water as solvents. All chemicals and reagents used in the study were reagent-grade chemicals. All the equipment and glassware used in the study were of analytical grade. Glassware such as Soxhlet extractors, separating funnels, test tubes, and beakers were thoroughly cleaned with a suitable detergent, rinsed with tap water, and then soaked in a chromic acid cleaning solution. All the equipment, like the hot air oven (Scope), heating mantle, centrifuge (Eltek- TC650D), autoclave (Scope), pH meter (Mettler-Toledo), sophisticated microscopes, etc., were provided by Apeejay Stya University.

Collection of Plant Material

Sugarcane bagasse (SB) was collected from the Palwal district (27.97°N; 77.42°E), Haryana, India. Many sugarcane species are cultivated in this district [17].

Dewaxing

Extraction and Isolation of cellulose from Sugarcane bagasse follows:

Collected raw material (SB) was allowed to air dry for 3-5 days, which was finely chopped and properly cleaned/washed with DM water to remove other contamination like soil, insects, dust, eggs, larvae, etc. Then, followed by hexane to get rid of any waxy and oil-related impurities. It was cut in about 4-5 cm length and air dried in shade for about 15 days. Using a grinding machine, the dried SB were crushed into a fine powder, sieved through a 30-mesh sieve, and then sealed in an airtight polyethylene bag for further examination [18].

Soxhlation

Most hydrophilic and hydrophobic contaminants were eliminated by Soxhlet extraction. A piece of clean cotton wool was used to block the opening of a porous thimble, into which 20g of SB powder was weighed and poured. Using distilled water for eight hours to remove hydrophilic impurities and a mixture of the 200mL of ethanol: toluene (1:2 v/v) solvents for an additional 10 hours to remove waxy impurities, a portion of the powdered sugarcane was first placed in a Soxhlet apparatus. The powder was then cleaned and mixed while suspended in hot distilled water. The powder was thoroughly rewashed with lots of water until the filtrate was clear after the filtrate was removed. The resultant powder was dried for 16-18 hours at 80°C- 90°C in a hot air oven, resulting in a yellowish solid with 99% conversion yield - unbleached bagasse - that was stored at room temperature in sterile, sealed containers [19].

Depulping and bleaching

400 mL of a 4% KOH solution with pH 12 was applied to the dewaxed powder and left at 90 °C for six hours. There were two repetitions of the treatment. The dewaxed powder was sifted and cleaned with distilled water following each application. After being alkali-treated, the dewaxed powder was treated for five hours at 70°C and pH 4.5 using 700 mL of 1.5% $NaClO_2$ in 80%

acetic acid. The bleaching was then done twice more. After allowing the bleached SB to cool, it was sieved and cleaned with distilled water until the pH of the filtrate was 7. Ultimately, an airtight plastic bag was used to preserve the pure white cellulose after it had been air-dried [20].

Delignification

The main components of SB after Soxhlet treatment were lignin and hemicellulose. The process was carried out using a modified technique from the literature. After drying, 10.05 g of Soxhlet residue was bleached with a 200mL of aqueous $NaClO_2$ solution (0.7% w/v) at a pulp-to-solution ratio of 1:50. The pH was then adjusted to 4 using a 5% acetic acid solution. The mixture was stirred for five hours at 70–75 °C using a magnetic stirrer (Remi-1MLH) set to 500–1000 rpm to extract lignin. The resulting yellow-brown residue was washed with hot distilled water (70 °C) until the filtrate became neutral. Both components were then dried in an oven at 80–100 °C. After drying, 6.82 g of sugarcane residue (68% yield) remained.

The residue was then agitated with 250 mL of a 5% (w/v) aqueous Na_2SO_3 solution for 5 hours. The sugarcane was rewashed with hot distilled water (70 °C). After washing, 4.68 g (46.8% yield) of cellulose was recovered as light-yellow particles, indicating the successful removal of some lignin and hemicellulose. The cellulose was then dried for 14 hours at 100°C [21].

Isolation of cellulose

The blended residue was subjected to an alkaline treatment. 4.68 g of cellulose, 250 mL volume of NaOH 17.5% (w/v) aqueous solution with pH of 12 was added. The mixture was stirred at 70 °C for five hours. After the residue was filtered, hot, distilled water (70 °C) was used to wash the filtrate and adjust its neutral pH (pH-7). The liquid was then decanted. The end product was a vivid yellow residue that demonstrated the loss of hemicellulose. A total of 2.14 g (21.4 % yield) of the product was utilized, with an additional 1.5 g being used for processing, and the remaining grams were stored for analysis [22].

Bleaching of crude cellulose

A 100 mL round-bottom flask was normally filled with 2 g of crude cellulose made from sugarcane bagasse and 20 mL of Na_2CO_3 and H_2O_2 (8% and 2 % weight in the mixture). After 10 hours of heating at 60°C, the mixture cooled to room temperature. SB cellulose was obtained by filtering the solid and drying it under vacuum for 1 hour at 50 °C [23]. The complete method is elaborated in **Figure 3**.

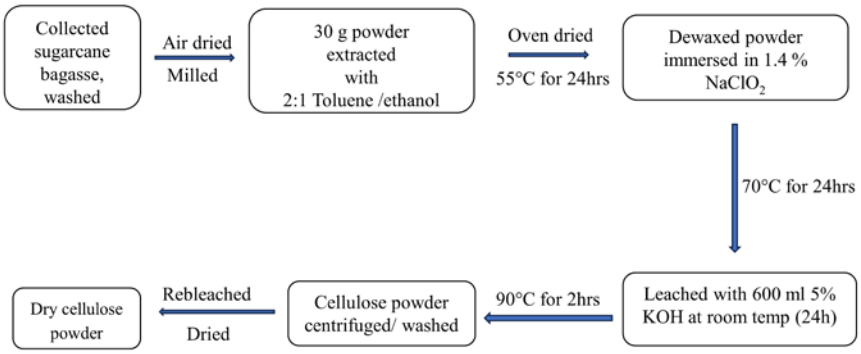

Figure 1: Flow Chart of extraction and isolation of cellulose from SB

Methods of the preparation of the Methylcellulose from SB cellulose

The methylation method was adapted & modified from the various published literature [24, 25]. Briefly, the specified amount of the coarsely pulverized SB was mercerized initially by adding 20 mL of the 50% sodium hydroxide solution (NaOH), which was kept on the rotary beaker shaker for 1hr at room temperature. The excess of the sodium hydroxide from the mercerized pulp was removed by filtering out the excess of the NaOH solution to a weight ratio of the NaOH solution to the pulp ratio of 3. The filtered mercerized pulp was subsequently added to 50 mL of iodomethane, and the mixture was shaken for an additional hour at room temperature. The reaction mixture was then subjected to reflux conditions at 60°C for 24 hours, with continuous shaking. The mercerization and methylation processes were repeated to achieve a higher degree of substitution. At the end of the reaction, the mixture was neutralized with 10% (v/v) of the acetic acid solution, vacuum filtered, and washed thrice with acetone and ethanol to remove the residual impurity, thus obtaining methylcellulose. The

obtained methyl cellulose with a percentage yield of 66% was then dried in an oven for 6 hours and stored in an airtight container for further analysis [26, 27].

Pharmacopoeial Characterization

The following Pharmacopoeial properties were tested for isolated cellulose [28, 29]

Identification

A watch glass containing 0.2 g of the extracted cellulose powder sample was placed in 2 mL of iodinated zinc chloride solution.

pH test

5 mL each of distilled and tap water were used to shake 0.1 g of the sample for 5 minutes. The liquid was tested for pH via a digital pH meter.

Starch test

5 mL of water was stirred with 0.1g of extracted cellulose, and 0.2 mL of 0.05 M iodine was added, and color change was observed.

Organic Impurities

A watch glass containing 0.2 mg of cellulose was covered with 0.5 mL of a rapidly made solution that contained 0.1 g of phloroglucinol in 5 mL of hydrochloric acid. There was no discernible change in color.

Solubility

The solubility of the cellulose and methyl cellulose obtained from SB was evaluated in different solvents, such as aqueous 2.5M HCl, 2.5 M H_2SO_4, Ethanol, Methanol, Toluene, Acetone, Phosphate buffer pH 2.5, pH 6.8, and Chloroform.

Ash Content

The inorganic residue left over after heating in the presence of air after the water and organic molecules have been eliminated is known as the ash value. It represents the total amount of minerals in a sample. A lower Ash value for the cellulose sample made from agricultural waste indicates a higher concentration of volatile materials and a lower inorganic content.

Loss on drying

All the obtained cellulose samples were heated in a hot air oven at 105°C for 3 to 4 hours to calculate the difference in their weight before and after drying.

Other Chemical tests

The isolated cellulose was acid (HCl) hydrolyzed in an autoclave at 121°C for 6 hours. After hydrolysis, chemical tests of carbohydrates, such as Fehling, Benedict, and Molisch tests, were performed, which resulted in positive observations. Besides, the degree of substitution of the methylcellulose was calculated according to the procedure described by Nassatto et al. [19].

Swelling ratio

10 mL of distilled water with varying pH (neutral-7 to basic-13) were filled in a test tube with 0.5g of cellulose and allowed to sit for 10 hours. The observation was noted. Swelling ratio studies revealed no significant swelling at pH 7, mild swelling at pH 8, and good swelling was observed at or above pH 11, as illustrated in **Figure 4**

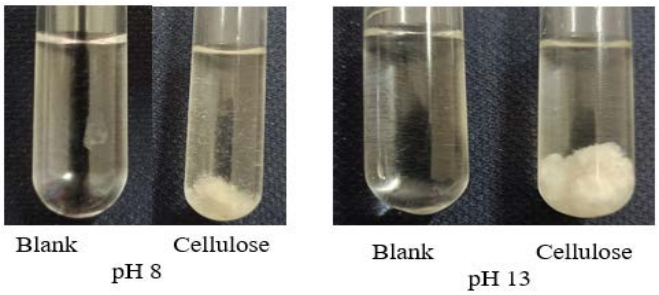

Figure 4: Swelling/Solubility of the cellulose

Micromeritics Characterisation

Pharmaceutical powders' micromeritic properties are crucial for solid drug delivery systems. Understanding the physiochemical characteristics of excipients and final products is essential for pharmaceutical work. Understanding and managing particle size is critical to materials science and pharmacy, as it helps formulate and deliver drugs effectively. Various tests for the micromeritic properties (Bulk and Tapped density, flow properties, Carr's index, Hausner's ratio, porosity, and angle of repose) are critical physical parameters that influence powdered materials' processing, handling, and end-use performance. These properties are essential for pharmaceutical and industrial applications as they directly impact manufacturing processes, product uniformity, dissolution rates, and overall quality control of the final products.

Optical microscopic analysis

The optical microscope images of the samples were captured using a KERN & SOHN advanced compound microscope (OBN-13). Both dark and bright field modes were employed to capture images at magnifications of 10x, 25x, and 40x.

Scanning electron microscopy

The samples' surface morphology, particle characteristics, structural features, and microstructural characteristics were investigated using Scanning Electron Microscopy (SEM) (JSM-IT200- JOEL) operated at an accelerating voltage of 10.00kV. Before imaging, the samples were mounted on aluminium stubs using double-sided carbon tape and sputter-coated with a thin

layer of gold to ensure stable conductivity. The images obtained were then analysed in suitable software to determine the average size or diameter of the samples.

FT-IR Analysis

Fourier Transform Infrared (FTIR) spectroscopic analysis was performed using a PerkinElmer Spectrum-2 and Bruker spectrometer to investigate the samples' functional groups and structural characteristics. The spectra ranged from 400 to 4000 cm^{-1} in the mid-infrared region. Each sample was subjected to 10 scans per measurement to enhance the signal-to-noise ratio and ensure spectral quality.

D.S.C. Analysis

Differential scanning calorimetry (DSC) was used to examine the thermoplastic characteristics of the isolated cellulose. The DSC-25 TA™ apparatus was employed for the analysis. Each sample, weighing about 8 mg, was placed in a crucible pan equipped with a perforated lid. Heating was conducted at a rate of 10 °C/min in the presence of nitrogen gas flowing at 50 mL/min, up to a temperature of 350°C. This procedure assisted in the determination of glass transition temperatures and melting points of the cellulose samples [30].

RESULTS

Pharmacopoeial Characterization

Various pharmacopoeial characterization tests were performed on the extracted cellulose and methyl cellulose samples [28]. In the identification test, the cellulose powder retained its original color when treated with an iodinated zinc chloride solution. The pH test revealed a neutral value of 7, and the starch test showed no color change with the iodine solution. The organic impurities test using phloroglucinol-hydrochloric acid solution showed no discernible color change. Solubility studies demonstrated that cellulose from both SB cellulose was insoluble in 2.5M HCl, 2.5M H_2SO_4, ethanol, methanol, toluene, acetone, phosphate buffers (pH 2.5 and 6.8), and chloroform, but was soluble in 2.5M NaOH. Methylcellulose from SB was insoluble in all tested solvents [27,31]. The ash content analysis indicated a lower inorganic content and higher volatile materials in the cellulose sample. Details are elaborated in **Table 1**. Chemical tests following acid hydrolysis (Fehling, Benedict, Molisch) also confirmed the presence of mono/disaccharides [32]. Substantial swelling of SB cellulose above pH 8 in an aqueous system indicates surface interactions because of interfacial properties. The Pharmacopoeial tests for the SB methylcellulose showed promising results compared to the industrial methylcellulose. Detailed elaboration is provided in **Table 2**.

Table 1: Pharmacopoeial properties of the cellulose extracted from SB and MCC

Properties	**SBC**	**MCC**
Identification	Violet-blue	Violet-blue
pH *	6.7±0.5	6.3±0.7
Starch Test	Nil	Nil
Organic Impurities*	Nil	Nil
Heavy Metals Impurities*	< 10 ppm	< 10 ppm
Purity (%)	96.05±5.62	99.34±1.56
Ash Content (%)	0.10±0.05	0.05±0.06
Moisture Content (%)	8.45±1.89	4.32±1.11
Appearance: Form, color, smell and taste	Fine amorphous/ crystalline powder, white, odorless and tasteless respectively	

*SBC=Sugarcane cellulose, MCC= Microcrystalline cellulose The data is expressed in mean ± SD, n=3

Table 2: Pharmacopoeial properties of the cellulose extracted from SBMC and IMC.

Properties	**SBMC**	**IMC**
Identification	Slight cloudiness occurs when heated to 50-60°C	Strong cloudiness occurs when heated to 50-60°C
pH *	6.8±0.5	6.6±0.7
Organic Impurities*	Nil	Nil
Heavy Metals Impurities*	< 10 ppm	< 10 ppm
Purity (%)	97.05±3.21	99.34±2.01
Ash Content (%)	0.560±0.16	0.1±0.4
Moisture Content (%)	6.45±0.04	5.12±2.89
Degree of substitution	1.14	2.1

*SBMC=Sugarcane derived methylcellulose, IMC= Industrial methylcellulose. The data is expressed in mean ± SD, n=3

Micromeritics characterization

Parameters like Carr's index, Hausner ratio, and angle of repose are crucial for excipient flow properties. As verified by the data in Table 3, a low Carr's index and Hausner ratio indicate good flowability and compressibility, essential for uniform tablet formation. A low angle of repose signifies excellent powder flow, ensuring consistent tablet weight and strength. Poor values in these parameters suggest handling and processing issues affecting tablet quality [33].

Table 3: Micromeritics Characterization of the SBC and MCC

Properties	**SBC**	**MCC**
Bulk Density (gm/cm^3)*	0.222±0.081	0.501±0.027
Tapped Density (gm/cm^3)*	0.718±0.034	0.714±0.058
True Density (gm/cm^3)*	1.681±0.041	1.550±0.062
Porosity (%)	86.794	67.677
Carr's Index	69.081	29.832
Hausner Ratio	3.234	1.425
Angle of Repose (°)*	45.637±0.422	36.050±1.741

*SBC=Sugarcane cellulose, MCC= Microcrystalline cellulose
The data is expressed in mean ± SD, n=3

Optical microscope

The KERN & SOHN (OBN-13) microscope observed cellulose extracted from sugarcane bagasse. Microscopic examination revealed differences in the cellulose extracted from these two sources, highlighting variations in their properties. The length of the cellulose fiber was found to be approx. 84 µm. A comparative representation of the cellulose is shown in Figure 5.

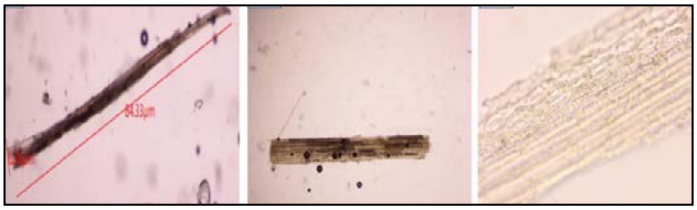

Figure 5: Optical microscopic images of cellulose extracted from sugarcane bagasse, including measurements and images at different magnifications

Scanning Electron Microscopy

Scanning electron microscopy (SEM) (JSM-IT200- JOEL) aims to observe a sample's surface morphology up close and learn more about the surface roughness. The white bar at the bottom of Figure 6 represents a length of 100 µm, and the image is 130 times magnified compared to the actual size in the sample of SB cellulose. A sample's morphological form is visible from three angles: the upper surface, the side surface, and the interior space surface. Based on particle shape analysis, the cellulose extracted chemically from SB was observed in solid form with a rod- or ribbon-shaped structure at great magnification. Their analysis of these SEM pictures with data from previously published literature revealed that the microcrystalline material made chemically from SB appears to be remarkably comparable to cellulose (MCC), which is sold commercially. SB cellulose, after micronization, can be successfully employed in various pharmaceutical applications, like MCC [34].

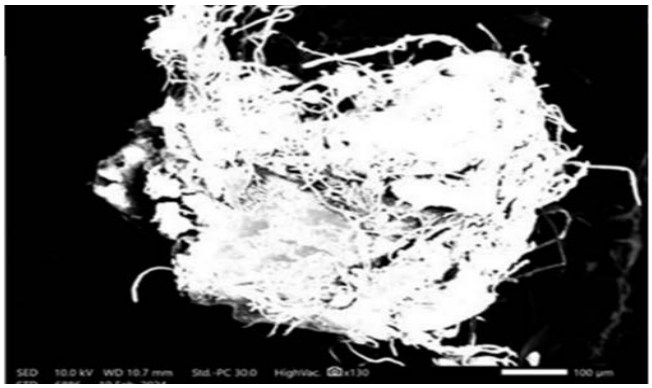

Figure 6: SEM images of Cellulose extracted from SB

FT-IR Analysis

Figures 7a and 7b present the FT-IR spectra of powdered sugarcane bagasse and the isolated, purified cellulose from sugarcane bagasse. In the spectra for all samples, a broad O-H stretching band was observed between 3500-3200 cm^{-1}. Additionally, a C-H stretching vibration was seen in the 2942-2811 cm-1 range, which is typical of cellulosic materials.

Absorbance peaks around 1652-1519 cm^{-1} correspond to the O-H bending of adsorbed water. Peaks around 1153-1011 cm^{-1} are attributed to the C-O-C pyranose ring stretching vibration. Another significant absorption band was observed at approximately 913-902 cm^{-1}, associated with the β-glycosidic linkages between glucose units. Figure 7c shows the characteristic peaks for identifying methyl cellulose formation. These peaks appear between 3500-3400 cm^{-1}, corresponding to C-H stretching, and between 2800-2900 cm^{-1}, corresponding to O-H stretching. The methylation process leads to an increased substitution of methyl groups, which enhances the intensity of the C-H and O-H absorption bands in the 2800-2900 cm^{-1} region [35, 36].

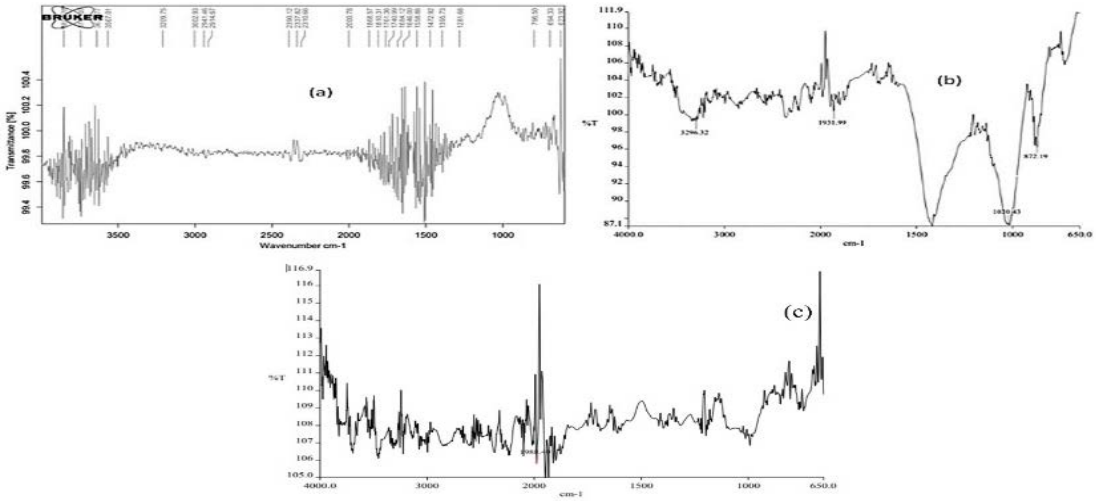

Figure 7: FTIR spectra of the (a) powdered SB, (b) isolated SB cellulose (c) methylcellulose from SB cellulose

DSC Analysis

Differential Scanning Calorimetry (DSC) was employed to determine the extracted cellulose's thermal properties, including energy consumption and thermal stability. The thermogram revealed the absence of sharp peaks, indicating the amorphous polymeric nature of the cellulose powder. DSC was thus used to examine the thermal characteristics of the isolated sugarcane cellulose, focusing on its energy consumption and thermal stability. **Figure 8** represents the DSC thermogram illustrating the thermal behavior of isolated SB cellulose across a temperature range from 50 °C to 350 °C. The initial endothermic transition of cellulose was observed between 60 °C and 150 °C, indicating the amorphous component's involvement and implying the molecular chain rearrangement. Additionally, a prominent exothermic peak was noted at 306.40 °C. Consequently, the DSC analysis confirms the exceptional thermal stability of the isolated cellulose derived from sugarcane cellulose [36, 37].

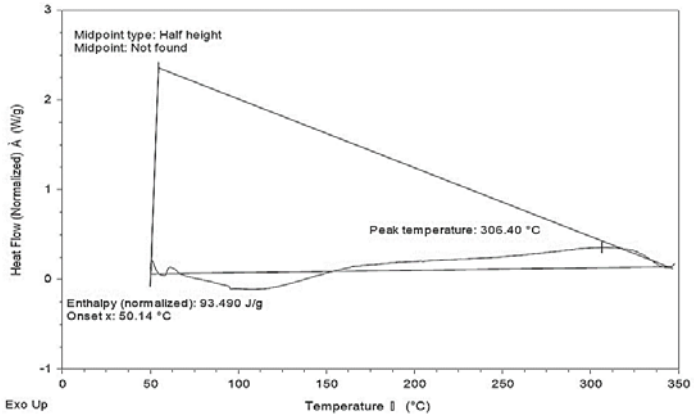

Figure 8: DSC thermogram of extracted sugarcane cellulose

CONCLUSION

Cellulose was successfully isolated and purified from sugarcane bagasse, and the products were characterized by chemical testing and FT-IR, DSC, NMR, microscopy/SEM, and also analyzed by physicochemical and micrometric tests. This cellulose obtained from the agri-waste does not have inferior flow properties compared to commercially available MCC. The isolated cellulose had amorphous material characteristics compared to crystalline MCC. Usually, the MCC originates from fresh wood pulp of dicot plants. In contrast, this waste sugarcane belongs to the botanical family of Poaceae and originated from monocot plants, which makes our method highly environment friendly and economical. Because of the origin diversity of the extracted cellulose [38], it may have lesser flow properties, high permeability, and higher strength [39]. This revealed important new facets of the most recent method for managing solid agricultural waste and a fresh source for cellulose manufacturing and its potential uses in the pharmaceutical and biomedical industry [40, 41]. Multidisciplinary and technical uses of these biopolymers (cellulose) and their derivatives in bioplastics, newly derived polymers, advanced materials, civil engineering, nanotechnology, fillers and filtration media, and excipients [42].

Today, available commercial cellulose is obtained from fresh pulpy wood, which is again obtained by cutting fresh/green trees; hereby, we employ raw material from waste [43]. These have a lot of potential for various technical applications, including bioplastics, polymer and selective filtration membranes, reinforcement agents, electrospinning fibers, and fillers for polymer matrices [44, 45].

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

Manoj Kumar Sharma conducted the literature survey, laboratory work, drafting, and further manuscript revision, while Anupama Diwan helped conceptualise the idea and oversaw the final decisions. Tanya Gupta helped re-draft the manuscript. Narender Yadav designed the research study, and Satish Sardana constantly guided the finalisation of the manuscript. M. K. Kumawat interpreted the analytical data.

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