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Extraction of Cellulose Fibre from Sugarcane Bagasse via Alkaline Hydrogen Peroxide (AHP) Hydrolysis: A Value-Added Approach to Industrial Waste

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Abstract
Sugarcane bagasse is the primary lignocellulose by-product of the sugar industry. While often used as a low-value fuel for boilers, its high cellulose content makes it an ideal precursor for industrial biopolymers. This study investigates the extraction of cellulose from sugarcane bagasse to provide a sustainable alternative to wood-based pulp and reduce the environmental footprint of sugar production. The extraction was performed using Alkaline Hydrogen Peroxide (AHP) hydrolysis, a process considered to solubilise lignin and hemicellulose while preserving the crystalline structure of the cellulose fibres. The raw bagasse was analysed for physicochemical analysis, including pH, organic carbon, available nitrogen, Phosphorus, potassium and ash content. For the extraction of cellulose, parameters were optimised at a temperature of 40°C and a pH of 11.5, using a liquid-to-sample ratio of 150 ml/g. The process achieved a significant cellulose yield, proving that bagasse is a highly efficient source for cellulose recovery. The study concludes that converting bagasse into cellulose fibres is financially viable and environmentally superior to simple combustion, offering a high-value application for sugar industry residues in the textile, paper, and pharmaceutical sectors.

Keywords: Sugarcane bagasse; Lignocellulose; Cellulose extraction; Alkaline hydrogen peroxide; Sustainable polymer

Introduction

Sugarcane is a tropical, perennial grass with multiple stems that reach a height of 3 to 4 meters and have a diameter of about 5cm (2 inches). When the stem matures, it is called a cane stalk, which constitutes around 75% of the entire plant. A mature stalk mainly composed of 11-16% fibre, 12-16% soluble sugars, 2-3% non-sugars, and 63-73% water. The average yield (24-28 tons per acre; 27-31 tons per acre) per year. This figure varies between 30 to 180 tons per hector depending on the approach of management of cultivation. Sugarcane is a cash crop, but it is also used as livestock fodder. India has been the origin of sugarcane and sugar. India is the second largest producer of sugar in the world after Brazil (Krishnamoorthy & Nandhini, 2017). The states of Uttar Pradesh, Bihar, Haryana, Maharashtra, Gujarat, Tamil Nadu, Andhra Pradesh, and Karnataka are classified into three groups according to their production capacity. The primary high-sugar-producing states are Maharashtra and Uttar Pradesh. In India, 78 percent of sugarcane is used for sugar production and 15 percent of the crop is used to produce various other products like jaggary and the remaining is used for bio-fuel production. (Nandhini & Padmavathy, 2017) Sugarcane bagasse is an excellent biomass resource in sugar-producing countries worldwide. The amount of cane bagasse produced depends on the plant variety which is harvested, age of the crop at harvest, soil and weather conditions of that region. Sugarcane bagasse contains about 40–50% cellulose and 25–35% hemicellulose. (Mahmud & Anannya, 2021) The composition makes bagasse an attractive source of natural fibres for various applications, including food packaging. (Magda et al., 2024). Plant-based biomass consists of lignocellulosic materials such as lignin, hemicellulose, and cellulose. Among plant-based biomass, agricultural by-products could serve as sustainable, renewable, and inexpensive raw materials to produce industrial biopolymers. (Shahi et al., 2020).

Material and Methods

The sugarcane bagasse was dried in sunlight for 8 to10 days. The finely powdered dried sugarcane bagasse was analysed for physicochemical analysis, including pH, organic carbon, available nitrogen, Phosphorus, potassium and ash content. The extraction process begins by weighing 5 g of fine-powdered, dried bagasse and placing it into a 1000 ml conical flask. To initiate the chemical treatment, a mixture of 1ml ethanol, a 3% NaOH solution, and a 30% H_2O_2 solution is added to the sample. The alkalinity of the mixture is carefully adjusted to maintain a pH of 11.5, ensuring a final liquid-to-sample ratio of 150 ml/g. Once the mixture is prepared, it undergoes hydrolysis for a duration of 6 hours. During this stage, the environment is kept at a constant temperature of 40°C while being agitated at 250 rpm using a magnetic stirrer. Following hydrolysis, the solution is neutralized using H_2SO_4 and processed through a vacuum filter to separate the solids. Finally, the extracted cellulose is thoroughly washed and dried to determine its initial weight, completing the recovery process.

Results and discussion

From analysis of bagasse indicates that the bagasse sample is a relatively clean starting material for cellulose recovery. The ash content (0.6%) is notably low, which is excellent; a lower mineral content means there are fewer inorganic impurities to interfere with the alkaline hydrolysis or contaminate the final cellulose yield. The Organic Carbon (8.5%) and Available Nitrogen (1.3%) suggest a moderate level of organic matter. From an extraction standpoint, the presence of Available Phosphorus (72 mg/kg) and Potassium (0.80%) represents the residual plant nutrients that will likely be washed away during the vacuum filtration and neutralization steps, leaving behind the structural carbohydrate i.e. Cellulose.

Table 1. Physiochemical parameters of raw sugarcane bagasse

Parameter	Value	Implications for Extraction
pH	7.4	Nearly neutral; suggests the raw material is stable and won't prematurely degrade before NaOH is added.
Organic Carbon	8.5%	Reflects the organic bulk of the sample, including the target cellulose.
Available Nitrogen	1.3%	Low nitrogen content is typical for bagasse, minimizing protein-based impurities.
Available Phosphorus	72 mg/kg	Trace mineral that will be removed during the washing/filtration phase.
Available Potassium	0.80%	Soluble inorganic component; easily removed during the neutralization step.
Ash Content	0.6%	Very Low. Indicates high purity and less likelihood of silica/mineral interference.

The chemical profile of the bagasse indicates a high-purity organic substrate. With an Ash Content of only 0.6%, the sample is remarkably free of inorganic residues that typically complicate the extraction of high-grade cellulose. The pH of 7.4 provides a stable baseline for the subsequent alkaline treatment. The C:N ratio of 6.54 confirms a carbon-rich profile, suggesting that the 6-hour hydrolysis at 40°C will be highly effective in isolating the carbon-based cellulose fibres from the remaining organic material. The extraction process performed on the sugarcane bagasse samples yielded significant results. The extraction process was validated through triplicate trials using 5.0 g samples of sugarcane bagasse. Starting with a raw sample mass of 5.0 g, the chemical treatment consisting of alkaline hydrolysis with 3% NaOH and 30% H_2O_2 successfully isolated 2.17 g of dried cellulose. This represents a total recovery yield of 43.0%.

Table 2. Yield percentage from sugarcane bagasse

Trial Number	Input (Bagasse)	Output (Cellulose)	Yield (%)
Reading 1	5.0 g	2.2 g	44.0%
Reading 2	5.0 g	1.9 g	38.0%
Reading 3	5.0 g	2.4 g	48.0%
Average	5.0 g	2.17 g	43.33%

Impact of Low Ash Content: The remarkably low ash content (0.6%) in the raw bagasse likely prevented mineral interference and silica scaling during the 6-hour hydrolysis. This allowed the NaOH and H_2O_2 to react more effectively with the lignocellulosic matrix. According to Kumar et al. (2021) and Sharma et al. (2025), sugarcane bagasse typically yields 40-45% cellulose.

Conclusion

The correlation between the initial chemical profile neutral pH and low inorganic impurities and the final recovery rate suggests that the extraction process is highly optimized for this specific sugarcane byproduct. The resulting 43% yield confirms that the process is capable of producing concentrated cellulose suitable for further industrial or laboratory applications. From an economic perspective, the extraction of cellulose from sugarcane bagasse represents a high-return 'waste-to-wealth' strategy. The 43% recovery rate achieved in this study is industrially competitive, especially when paired with the exceptionally low ash content (0.6%) which minimizes pre-treatment costs and chemical waste.

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KVP and SM conceived the concept, wrote and approved the manuscript.

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