

**EXTRACTION AND ACETYLATION OF CELLULOSE FROM *Sporobolus
Pyramidalis* (GIANT RAT TAIL GRASS)**

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BENIN CITY**

FEBRUARY, 2025

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**BEING A PROJECT SUBMITTED TO THE DEPARTMENT OF
CHEMISTRY, FACULTY OF PHYSICAL SCIENCES, UNIVERSITY OF
BENIN, BENIN CITY. IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE AWARD OF THE BACHELOR OF SCIENCE
(B.Sc.) DEGREE IN INDUSTRIAL CHEMISTRY, UNIVERSITY OF BENIN**

FEBRUARY, 2025

CERTIFICATION

This is to certify that the research work titled “**Extraction and Acetylation of Cellulose from *Sporobolus Pyramidalis* (Giant Rat Tail Grass)**” was carried out by **ODERHOHWO ESEOGHENE FAVOUR** with Matriculation Number: **PSC2008062** in the Department of Chemistry, Faculty of Physical Sciences, University of Benin, Benin City, in partial fulfilment of the requirement for the award of Bachelor of Science (B.Sc) degree in Industrial Chemistry, University of Benin, Benin City.

DR. A.E. AIWONEGBE

(Project Supervisor)

DATE

PROF. E.E.I IRABOR

(Head of Department)

DATE

DEDICATION

I humbly dedicate this research project to God Almighty, whose boundless grace, wisdom, mercy and unwavering guidance has made this endeavor a success and guided me through at the esteemed University of Benin.

In addition, I dedicate this project in Honor of my beloved parents Mr. and Mrs. Oderhohwo.

ACKNOWLEDGMENT

I would like to express my sincere gratitude to Dr. A.E Aiwonegbe for his invaluable guidance and support throughout this research. Special thanks to the Department of Chemistry, University of Benin for providing the necessary equipment and resources for conducting the experiments. I also extend my appreciation to my colleagues Jerry, Sharon, Cherry and Oliver for their helpful insights and assistance during the experimental process. Lastly, I acknowledge the financial support from my parents Mr and Mrs Oderhohwo and my other sponsors without which this work would not have been possible.

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ABSTRACT

This study investigates the extraction and acetylation of cellulose from *Sporobolus pyramidalis*, commonly known as Giant Rat Tail Grass, an abundant yet underutilized plant species. Cellulose was extracted through a series of chemical treatments, including alkali and bleaching processes, to remove lignin, hemicellulose, and other non-cellulosic components. The extracted cellulose was characterized using Fourier-transform infrared spectroscopy (FTIR), which showed peaks closely matching those of commercial cellulose. Scanning electron microscopy (SEM) was also employed to confirm the structure of the extracted cellulose. The cellulose was then acetylated using acetic anhydride and sulfuric acid to enhance its thermal stability, hydrophobicity, and solubility. FTIR analysis confirmed the successful acetylation, with peaks closely aligning with those of commercial cellulose acetate. The acetylated cellulose exhibited improved properties, including enhanced solubility in organic solvents and thermoplasticity, making it suitable for use in bioplastics, coatings, and other biodegradable materials. This research highlights the potential of *Sporobolus pyramidalis* as a renewable source of cellulose and contributes to the development of sustainable, biomass-based materials.

CHAPTER ONE

1.0 Introduction

There has been increasing global demand in recent years for renewable sources of food and energy and this has led largely to a strain on natural resources, deforestation, exacerbating climate change and water pollution to site a few. In response to this, interest have risen in renewable and sustainable alternatives to the known fossil fuels and agricultural practices. Currently immense quantities of agricultural residues are generated worldwide. Although they are available abundantly and are renewable sources for organic substances, still considerable amount of these wastes is not used in a proper manner.

Conversion of these agricultural wastes into valuable bio-based products can help in reducing the environmental problems (vikas *et al*, 2021)

1.1 Background of the Study

Cellulose- a widely used polysaccharide is the most abundant organic compound in plant cell wall, Its unique properties make it both a versatile and ideal raw material for application in the pharmaceutical, packaging, construction, biofuel, textiles, food and paper industries (Ikese *et al.*, 2022) Traditionally, cellulose is obtained from wood pulp and cotton, but growing concerns about deforestation, land use, and environmental sustainability have pushed the search for other cellulose sources. Giant Rattail Grass (*Sporobolus pyramidalis.*), a dryland plant, has been identified as a promising yet underused source of cellulose. It grows quickly, thrives in different environments, and is often considered an invasive plant, making it an

excellent candidate for sustainable cellulose production among all the cellulose-derived products, cellulose acetate (CA) is the one that has been widely produced for thermoplastics. Cellulose acetate was successfully applied for the preparation of membranes in different membrane technologies, for wastewater treatment containing heavy metals or metallic ions, film packaging, in the textile industry, medical engineering, and in gas separation (Cindradewi *et al.*, 2021) Producing cellulose acetate from alternative sources, such as Giant Rattail Grass, presents an environmentally friendly option to meet the rising demand for sustainable materials. However, there is limited research on extracting, characterizing, and converting cellulose from Giant Rattail Grass into cellulose acetate. Addressing this gap is essential for promoting the use of renewable materials from unconventional sources.

1.2 Statement of the Problem

The global focus on sustainability and environmentally friendly technologies has increased the need for alternative cellulose sources that don't cause deforestation or compete with food crops while wood pulp and cotton are the main sources of cellulose, they are increasingly affected by environmental issues and land-use limitations. This overreliance on fibrous wood is linked to significant environmental problems, including deforestation, greenhouse gas emissions, and global warming [5]. Other raw material that also bear cellulosic fiber structures, such as non-woody plants, could therefore be considered (Worku *et al.*, 2023). Giant Rattail Grass, a fast-growing dryland plant, could serve as a more sustainable and affordable source of cellulose. However, the process of extracting and converting cellulose from

Giant Rattail Grass into cellulose acetate has not been thoroughly studied. The challenge is to create effective, scalable methods to extract high-quality cellulose from Giant Rattail Grass and convert it into cellulose acetate for industrial applications. This research aims to fill that gap by investigating these processes.

1.3 Justification of the Study

The increased demand for bio-based, carbon-neutral, and renewable feedstocks to replace fossil fuels for various industrial applications has led to renewed research interest in renewable feedstock sources (Lopez *et al.*, 2023). Giant Rattail Grass, which is often seen as an invasive species, is an ideal choice for cellulose extraction because of its high cellulose content, fast growth, and ability to adapt to various environments. Using Giant Rattail Grass for cellulose extraction not only provides an alternative source but also helps control its spread in areas where it is considered a pest. Additionally, making cellulose acetate from non-wood sources could greatly reduce the environmental impact of traditional cellulose production. The conversion of cellulose from rattail into cellulose acetate could offer a biodegradable substitute for petroleum-based plastics and decrease reliance on non-renewable materials. This research supports global efforts to promote a circular economy and lessen the environmental damage caused by industrial activities.

1.4 Aim and Objectives

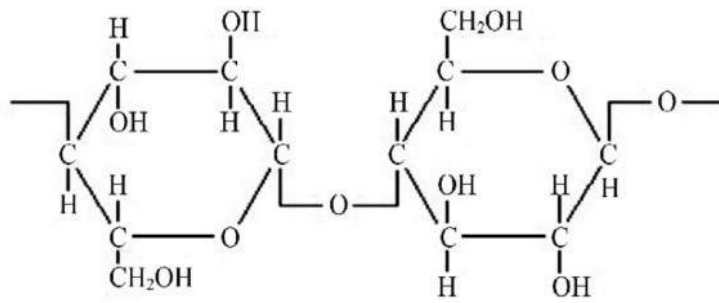
Aim: This study aims to extract cellulose from Giant Rattail Grass, analyze its properties, and convert it into cellulose acetate

Objectives:

The objective of this study is to:

1. Extract cellulose from Giant Rattail Grass using alkaline and mechanical methods
2. Analyze the extracted cellulose using Fourier-transform infrared spectroscopy (FTIR) and Scanning Electron Microscopy (SEM) to evaluate its chemical structure and crystallinity
3. Convert the extracted cellulose into cellulose acetate through acetylation reactions
4. Assess the properties of the cellulose acetate produced from Giant Rattail Grass
5. Compare the properties of cellulose acetate derived from Giant Rattail Grass with commercial cellulose acetate.

1.5 Literature review



Cellulose

1.5.1 Structure

Cellulose is the principal component of plant cell walls and the most abundant source of renewable polysaccharides on Earth (Sharma et al., 2019). Cellulose is insoluble in water and most organic solvents due to its extensive hydrogen bonding and the linear arrangement of glucose molecules. Its high molecular weight, crystalline structure, and hydrogen bonding give it exceptional mechanical strength, making it an ideal material for various applications (Etale *et al.*, 2023).

"Nevertheless, Certain microorganisms and enzymes can decompose cellulose into glucose through hydrolysis, facilitating various industrial processes"

Monomer unit

Cellulose is composed of β -d-glucopyranose units joined by β -(1,4) glycosidic linkages, with cellobiose as the primary repeating unit. Cellulose microfibrils are clusters of 500–1400d-glucose units with long cellulose chains that are organized to form cellulose (Zoghلامي., 2019)

The complex multilevel structure of cellulose is composed of bundles or aggregates of ultrafine fibrils where the various cellulose chains are present in the superfine fibril and each of the fibrils is made up of repeated large ordered (crystalline) and small disordered (amorphous) domains with cross-sectional dimensions ranging from 2 to 20 nm (Ioelovich, 2015; Kargarzadeh *et al.*, 2017).

1.5.2 Chemical formula

Cellulose has a chemical formula of $(C_6H_{10}O_5)_n$

Elemental composition -the elemental composition of cellulose is

Carbon(C) 44.4%

Hydrogen (H):6.2%

Oxygen (O):49.4%

1.5.3 Application of cellulose

•Applications in bio-adhesive and mucoadhesive drug delivery systems

Bio-adhesives and muco-adhesives are drug containing polymeric films with ability of adhering to biological membranes after combining with moisture or mucus compounds. Bio-adhesives were developed in mid 1980s as a new idea in drug delivery and nowadays they have been accepted as a promising strategies to prolong the residence time and to improve specific localization of drug delivery systems on various biological membranes.

•Building and construction industry

Cellulose is widely used as a sustainable insulation material in buildings and is also used as an additive in cement to improve workability and reduce water absorption

•Cellulose nanomaterials

In the modern world, different industries, namely food, consumer goods, military, construction, and so on, demand for renewable materials that possess the properties of biodegradability, are non-petroleum-based, carbon neutral; and have low environmental, animal/human health, and safety risks. Traditional cellulose materials are well-renowned biodegradable material produced from sustainable environment.

• Biofuel

Cellulosic biofuels offer environmental benefits not available from grain-based biofuels and are a cornerstone of efforts to meet transportation fuel needs in a future low-carbon economy, even with electrified vehicles and other advances. Bioenergy with carbon capture and storage (BECCS) is also key to almost all Intergovernmental Panel on Climate Change mitigation scenarios that constrain end-of-century atmospheric CO₂ to 450 parts per million.

• Agricultural uses

Cellulose based Fertilizers-Cellulose-based fertilizers have garnered significant interest because they can be released in a controlled way and are environmentally

friendly. Researchers have shown that fertilizer nutrients incorporated into a cellulose-based matrix allow controlled release, improve the efficiency of nutrient utilization, and reduce environmental impact

Cellulose-based fertilizers offer a more environmentally friendly alternative to conventional ones, with sustainable agriculture progressively exploring their potential. These fertilizers utilize widely distributed natural biopolymers like cellulose and its derivatives, including nanocrystalline cellulose (CNC), known for their unique agricultural functionalities

1.5.4 Definition of Cellulose Acetate

Cellulose acetate is a material made from cellulose a natural substance found in plants. It's created by reacting cellulose with acetic acid, resulting in a strong, flexible, and clear material. Cellulose acetate is popular because it breaks down naturally, making it a more environmentally friendly option compared to many plastics.

1.5.5 Importance of Cellulose Acetate

1. Biodegradable:

- Unlike regular plastic, cellulose acetate breaks down naturally in the environment. This makes it a good option for reducing plastic waste and pollution

2. Useful in Many Industries:

- Because it is strong, flexible, and easy to shape, cellulose acetate can be used in many different industries, making it a valuable material

3. Eco-friendly Option:

- Since cellulose acetate is made from renewable resources like wood or cotton, it helps lower the demand for plastics made from oil. This makes it a better choice for the environment

4. Supports Sustainable Products:

- As more companies look for greener alternatives, cellulose acetate is being used more in packaging, fashion, and other industries because of its biodegradability

1.5.6 Uses of Cellulose Acetate

1. Clothing and Fabrics:

- Cellulose acetate is used to make fabrics that are soft and absorbent. It is often used in clothing and home items like curtains and cushions. It's also used in cigarette filters.

2. Clear Plastic Films:

- It's often used to make clear plastic wraps for packaging because of its strength, clarity, and ability to break down naturally over time.

3. Eyeglass Frames:

- Many eyeglass frames are made from cellulose acetate because it is strong, lightweight, and can be easily dyed into different colors, making it stylish and durable.

4. Photography Film:

- Cellulose acetate was once widely used to make film for cameras. While digital photography has mostly replaced this, it's still used in certain specialized types of film.

5. Filters and Membranes:

- It's used in making filters for water systems and medical devices like dialysis machines. The material's tiny pores make it great for separating substances.

6. Biodegradable Plastic:

- Cellulose acetate can be used to make plastic products like bags and food containers that are biodegradable, helping to reduce plastic pollution.

7. Medical and Drug Use:

- In medicine, cellulose acetate is used in things like drug capsules and wound dressings because it can break down safely in the body. This makes it useful for healthcare products.

1.5.7 Definition of Biomass

Biomass is any material that comes from living things, like plants, animals, or waste. It can be used to create energy. Biomass includes wood, plant leftovers, animal manure, and even some types of waste. Biomass stores energy from the sun because plants absorb sunlight through photosynthesis. When we use biomass for energy, we release the stored energy.

1.5.8 Uses of Biomass

1. Energy Production:

- Biomass can be burned to produce heat and electricity. It is used in power plants and home heating systems, helping to replace fossil fuels.

2. Biofuels:

- Biomass can be processed into fuels like ethanol and biodiesel, which are used in vehicles. These fuels are renewable and produce fewer harmful emissions.

3. Biogas Production:

- Waste materials like animal manure and food scraps can be turned into biogas, which can be used as a source of energy for cooking, heating, and generating electricity.

4. Industrial Products:

- Biomass is used to make eco-friendly products like biodegradable plastics and chemicals. This reduces the need for oil-based products.

5. Fertilizer:

- After biomass is used for energy, the leftover material can be used as fertilizer to enrich soil, especially crop and animal waste.

1.5.9 Relevance of Biomass

1. Renewable Energy Source:

- Biomass can be replenished much faster than fossil fuels, making it a sustainable energy option.

2. Reduces Greenhouse Gas Emissions:

- Biomass releases carbon dioxide when used for energy, but this is balanced by the fact that the plants used to make biomass absorbed the same amount of carbon when they were growing. This helps reduce the overall carbon footprint.

3. Waste Reduction:

- Biomass helps reduce waste by converting organic materials like crop leftovers and food waste into energy and fertilizers, keeping them out of landfills.

4. Supports Rural Economies:

- The use of biomass, especially from farm and forest leftovers, provides jobs and income for people in rural areas.

5. Energy Security:

- By using local biomass resources, countries can reduce their dependence on imported fuels, improving their energy security.

1.5.10 Biomass from which cellulose can be sourced

Woody biomass

Woody biomass refers to biomass derived from woody materials such as tree, sawmill residues, and forest residues (Konstantinavičienė & Vitunskienė, 2023).

Woody biomass is the most prevalent organic material on earth and renewable energy with varying compositions of cellulose, hemicellulose and lignin depending on the tree species accounting for about 90–95 % of all cellulosic pulp produced (Jin *et al.*, 2021).

Woody biomass is classified into softwood (coniferous trees like pine, fir, and spruce) and hardwood (deciduous trees such as birch, aspen, and oak). Hardwood fibers are notably shorter and thinner than softwood fibers. Hardwood typically has less lignin and more cellulose and hemicellulose, whereas softwood has a higher concentration of extractives, such as resin (Suota *et al.*, 2021). The hemicellulose and cellulose fractions of wood represent renewable sources of sugar that can be used to produce biofuels (Zhang *et al.*, 2015).

Non-woody biomass

Non-wood biomass refers to all sources of lignocellulosic biomass other than woody plants (Owonubi *et al.*, 2021). The yield of non-woody biomass is enormous and has considerable potential as a feedstock for cellulose production (Alila *et al.*, 2013). The benefit of dedicated energy crops such as guinea grass and giant rat tail grass includes high cellulose content, rapid growth, and potential for sustainable

cultivation. The advantage of using non-wood lignocellulose biomass as a cellulose source include, low cost, availability, abundance and the waste reduction that would have resulted from their disposal through landfilling or incineration (Owonubi *et al.*, 2021). The extraction of cellulose from non-wood sources also requires reduced chemical and energy consumption because of its relatively low lignin content compared to wood, which often contains high lignin and requires high chemical and energy (Bajpai, 2018).

Agricultural crop residue

Agricultural crop residues refer to the non-edible parts of the crop left after harvesting and processing crops such as rice, corn, and wheat. They include primary or field-based agricultural residues that are generated during harvest, and secondary residues that are processed-based residues formed concurrently with the product during processing. They are considered an important source of cellulose to produce bioethanol, as they do not compete with food crops (Mohammed *et al.*, 2018).

Municipal and industrial waste

Municipal solid waste (MSW) refers to the varied types of waste generated in urban areas, including household, commercial, and food industry waste. It includes materials like paper, cardboard, food waste, yard trimmings, and textiles. In particular, the food industry generates a significant amount of waste, including various by-products and residues that can potentially be used as a source of cellulose (Munawar *et al.*, 2023). Pomace from the manufacture of fruit juice and

wine, such as grape skins, apple pomace, and citrus peels, as well as leftover vegetables, such as potato peels, carrot tops, and other scraps, are examples of food waste that can be used as a source of cellulose (Dilucia *et al.*, 2020). However, several variables can affect the feasibility of extracting cellulose from food industry waste, such as the type of waste, the processing techniques employed, and the desired level of cellulose purity (Dilucia *et al.*, 2020).

Other source of cellulose

Cellulose is also produced by bacteria, primarily those belonging to the genera *Acetobacter*, *Sarcina ventriculi*, and *Agrobacterium* (Fernandes *et al.*, 2020). Bacterial or microbial cellulose differs from plant cellulose in that it has a higher purity, strength, moldability, and water-holding capacity. Most bacteria in their natural habitats generate extracellular polysaccharides such as cellulose, which form protective envelopes around the cells (Wang *et al.*, 2019).

1.5.11 Giant Rattail Grass (*Sporobolus pyramidalis*)



Definition of Giant Rattail Grass (*Sporobolus pyramidalis*)

Giant Rat tail grass typically thrives in low-fertility soils, and it is often found in areas with poor soil, heavy grazing, or disturbance, where it can outcompete other grasses.

Scientific classification

- Kingdom: Plantae
- Phylum: Tracheophyta
- Class: Liliopsida
- Order: Poales
- Family: Poaceae
- Genus: *Sporobolus*
- Species: *Pyramidalis*

1.5.12 Relevance with Cellulose

Giant rat tail grass contains a lot of cellulose, which is a natural material found in the walls of plant cells. Cellulose helps give plants structure and strength. Because Giant Rattail Grass grows so fast and in large amounts, it's considered a good renewable source of cellulose. This cellulose can be extracted and used to make products like cellulose acetate, which is used in things like biodegradable plastics, films, and fabrics (Gomes *et al.* 2020). Using Giant Rattail Grass as a source of cellulose is beneficial because it's eco-friendly and sustainable (Zhou *et al.* 2018).

The percentage of cellulose that can be extracted from giant rattail grass (*Sporobolus pyramidalis*) is typically around 30% to 50% of its dry weight, depending on the specific part of the plant and the extraction method used (Bhavsar *et al.* 2020; Gomes *et al.* 2020). The leaves and stems generally contain the highest concentration of cellulose

CHAPTER TWO

MATERIALS AND METHODS

2.1 Apparatus

Mortar and pestle or grinder

Beakers

Heat source (hot plate)

Filtration setup (filter paper, funnel)

Oven or drying equipment

pH meter or pH strips

Analytical balance

Separatory funnel (for washing)

Reagents:

Sodium hydroxide (NaOH) solution (10% w/v)

Acetic acid (CH₃COOH) (1M)

Distilled water

Ethanol (95% or absolute)

Hydrochloric acid (HCl) (1M) for neutralization

2.2 Methodology

2.2.1 Collection of samples

The sample (*sporobolous pyramidalis*) which were used for the research were obtained from the faculty of agriculture animal farm, university of Benin, Benin city.

The plant was identified by “Prof. Akinobosun Henry Adewale” at the department of plant Biology and biotechnology, Herbarium unit, Faculty of Life Sciences, University of Benin, Benin city. Nigeria. Voucher number: UBH-S263

2.2.2 Extraction process of cellulose from rat tail grass

The procedure began with the collection of fresh or dry grass biomass, which was then dried at room temperature for 3-4 weeks. Once dried, the biomass was ground into a fine powder with a particle size of about 1-2 mm.

In the pretreatment stage, a 10% (w/v) NaOH solution was prepared by dissolving 50 g of NaOH in 500 mL of distilled water. Then, 50 g of the biomass powder was added to the NaOH solution, stirred continuously at room temperature for 2-3 hours, and the mixture was subsequently heated to 60°C, where it was maintained for an additional 2-3 hours with continuous stirring. After treatment, the mixture was filtered using filter paper to separate the solid residue from the NaOH solution, and the residue was rinsed with distilled water until the pH was neutral, requiring several washes.

In the acid hydrolysis step, a 5M acetic acid solution was prepared by diluting 28.5 mL of glacial acetic acid in 200 mL of distilled water. The neutralized biomass was added to 200 mL of this 5M acetic acid solution, heated to 80°C, and maintained at this temperature for 1 hour with occasional stirring. The mixture was then filtered to collect the solid residue, which was rinsed with distilled water, followed by a wash with 95% ethanol to remove non-cellulosic materials.

For the purification process, the sample was treated with HCl to neutralize any remaining acids, with a pH meter used to ensure neutrality. The cellulose was washed with distilled water until the wash ran clear. Finally, the cellulose was dried in an oven at 60°C for approximately 24 hours and stored in a desiccator to maintain dryness.

2.2.3 Characterization

1. Fourier transform infrared spectroscopy (FTIR)

1g of each sample Fourier transform infrared spectroscopy (FTIR) is a method for analyzing the absorption or emission spectrum of a solid, liquid, or gas sample. An FTIR spectrometer collects spectral data in high resolutions and simultaneously records multiple spectral intervals. This provides a distinct edge over a dispersive spectrometer that records intensity stepwise for small parts of the spectrum. The Fourier transform infrared spectroscopy (FTIR) analysis of the cellulose was performed using the

Agilent Technology Cary 630, was manufactured by Agilent Technologies, USA in 2011.

2. Scanning Electron Microscope (SEM) Analysis

The scanning electron microscopy (SEM) was performed to examine the physical structure change of the samples using SEM model Phenom ProX, by phenom World Eindhoven, The Netherlands. Sample was placed on double adhesive which was on a sample stub, was coated sputter coater by quorum technologies model Q150R, with 5nm of gold. Thereafter it was taken to the chamber of SEM machine where it was

viewed via NaVCaM for focusing and little adjustment, it was then transferred to SEM mode, was focused and brightness contrasting was automatically adjusted, afterward the morphologies of different magnification was store in a USB stick. SEM analysis was carried out to examine the physical structural changes of the sample using an SEM model Phenom ProX, a high-resolution electron microscope manufactured by Phenom World, Eindhoven, The Netherlands in year 2011.

2.3 Conversion of cellulose extracted from *Sporobolus pyramidalis* into cellulose acetate

Converting cellulose to cellulose acetate involves a chemical reaction called acetylation.

2.3.1 Materials needed

- Cellulose (e.g., wood pulp, cotton linters)
- Acetic anhydride
- Sulfuric acid (catalyst)
- Glacial acetic acid
- Water
- Filter aid (e.g., diatomaceous earth)

2.3.2 Equipment needed

- Reactor vessel
- Stirrer
- Heater
- Condenser

- Filter press
- Centrifuge

2.3.3 Process Steps

The procedure began with the pre-treatment of cellulose, where it was treated with a solvent, such as glacial acetic acid, to remove impurities and increase its reactivity. In the acetylation step, the pre-treated cellulose was mixed with acetic anhydride and sulfuric acid in a reactor vessel. The mixture was heated to 50-60°C (122-140°F) and stirred for several hours. During the reaction, the acetylation process converted the hydroxyl groups in the cellulose into acetate groups, forming cellulose acetate. Once the reaction was complete, water was added to the mixture to neutralize the acid and stop the reaction. The resulting cellulose acetate was then washed with water to remove impurities. Following washing, the cellulose acetate was filtered using a filter aid, such as diatomaceous earth, to aid in the separation of solid materials. After filtering, the cellulose acetate was centrifuged to remove any excess water. Finally, the cellulose acetate was dried to a moisture content of around 5%.

2.3.4 Characterization

1. Fourier transform infrared spectroscopy (FTIR)

1g of each sample Fourier transform infrared spectroscopy (FTIR) is a method for analyzing the absorption or emission spectrum of a solid, liquid, or gas sample. An FTIR spectrometer collects spectral data in high resolutions and simultaneously

records multiple spectral intervals. This provides a distinct edge over a dispersive spectrometer that records intensity stepwise for small parts of the spectrum.

2. Solubility in ethanol

Using solubility in ethanol as a test for cellulose acetate can help determine the degree of substitution (DS) and the quality of the cellulose acetate produced. The degree of substitution refers to the number of hydroxyl groups in the cellulose that have been replaced by acetate groups during the acetylation process.

Principle:

- Cellulose acetate with a high degree of substitution (close to a fully acetylated product) tends to be soluble in organic solvents like acetone, but insoluble in ethanol.
- Partially substituted cellulose acetate (with a lower DS) may be partially soluble in ethanol, depending on the degree of substitution.

CHAPTER THREE

RESULTS AND DISCUSSION

3.0 Yield of cellulose from the sample of Rattail grass

Percentage yield of cellulose from 50 grams of rat tail grass

$$\text{Yield} = (\text{Initial amount of grass} / \text{amount of cellulose obtained}) \times 100$$

In this case:

$$\text{Cellulose (\%)} = M2/M1 \times 100$$

- Amount of cellulose obtained = 32 grams
- Initial amount of grass = 50 grams

Now plug the values into the formula:

$$\% \text{ Yield} = 32/50 \times 100$$

$$\text{Yield} = (32/50) \times 100 = 64\%$$

So, the yield of cellulose from the cattail grass is 64%.

3.1.0 Results of the Characterization done on cellulose

3.1.1 Fourier transform infrared spectroscopy (FTIR) analysis of the sample of cellulose derived from rattail grass

The FTIR spectrum of the cellulose sample ("RTC SAMPLE 1g") was obtained to identify the functional groups and confirm the chemical composition of the sample.

The spectrum is shown in Figure 1.

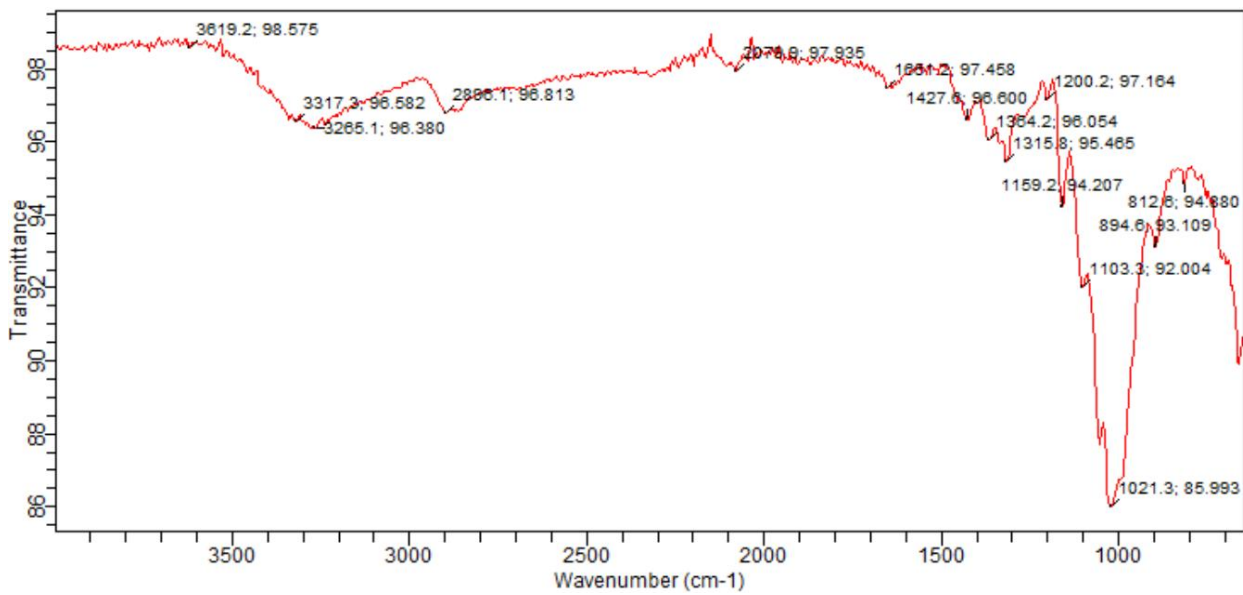


Figure 3.1: FTIR Spectrum of the (Rattail grass cellulose)

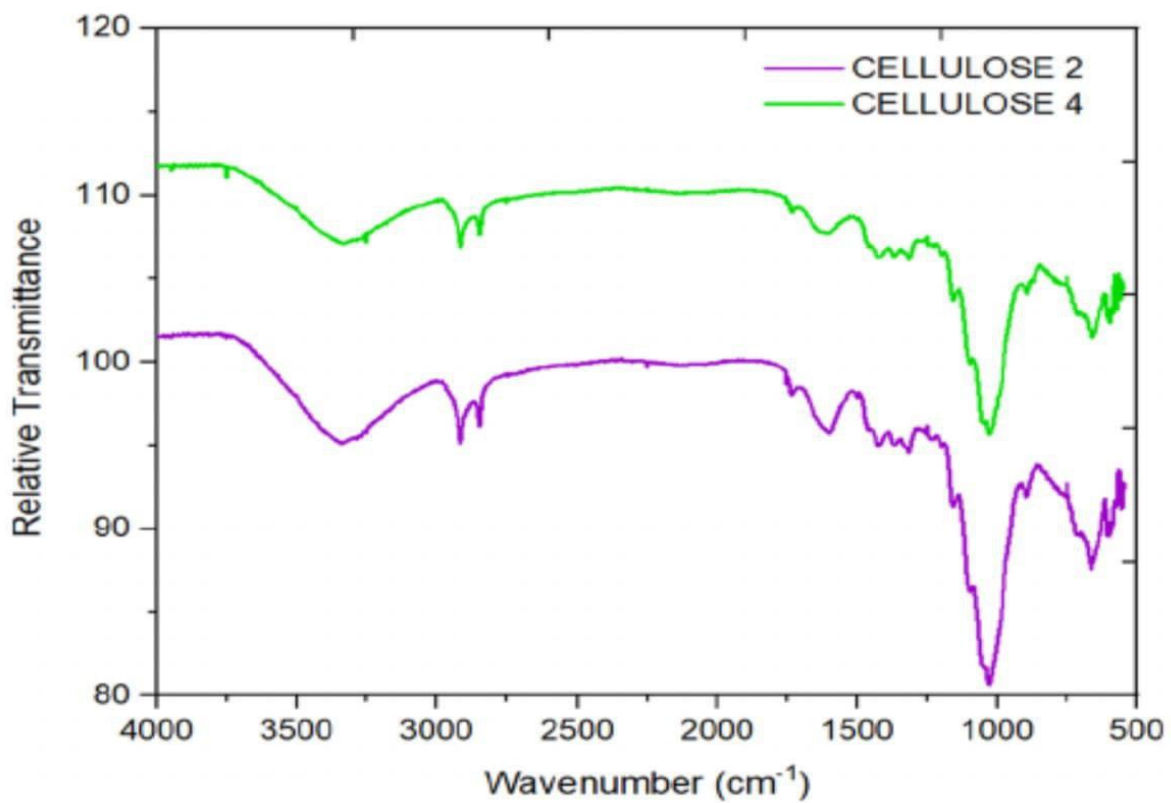


Figure 3.2: FTIR spectra of pure cellulose extracted from date palm leaves. Cellulose 2 represents cellulose extracted from ground leaves treated with 48% NaClO, and Cellulose

4 represents cellulose extracted from ground leaves treated with 64.0% NaClO. (Al-Awa et al., 2023)

The FTIR spectrum of the sample displayed several characteristic peaks, which are consistent with the structure of cellulose. The key absorption bands and their corresponding functional groups are summarized in Table 1.

Table 3.1: Major FTIR Absorption Bands of the RTC Cellulose Sample

Wavenumber (cm ⁻¹)	Functional Group	Assignment
3317 cm ⁻¹	O-H stretching	Hydrogen-bonded hydroxyl groups
2900 cm ⁻¹	C-H stretching	Aliphatic hydrocarbons (CH ₂)
1427 cm ⁻¹	C-H bending	Methylene group
1103 cm ⁻¹	C-O stretching	C-OH and glycosidic linkages
1021 cm ⁻¹	C-O stretching	Glycosidic linkages (C-O-C)
897 cm ⁻¹	β-glycosidic linkage	β-linkage between glucose units

The broad absorption peak at 3317 cm⁻¹ is characteristic of the O-H stretching vibrations, which are attributed to the extensive hydrogen bonding in the cellulose chains. This peak is typically broad due to the interaction between hydroxyl groups within the polysaccharide structure. A peak at 2900 cm⁻¹ corresponds to C-H stretching vibrations from the aliphatic hydrocarbon chains of cellulose. This peak

represents the methylene (CH₂) and methyl (CH₃) groups present in the glucose units of cellulose. The peaks at 1103 cm⁻¹ and 1021 cm⁻¹ are associated with C-O stretching vibrations, which are primarily due to the glycosidic linkages (C-O-C) between the glucose units in cellulose. These strong peaks confirm the polymeric nature of the cellulose sample. The peak at 897 cm⁻¹ is indicative of the β-glycosidic linkage between the glucose monomers, a hallmark of cellulose structure. No significant peaks indicative of other functional groups, such as carbonyl groups or aromatic compounds, were observed, suggesting that the sample is largely composed of pure or minimally processed cellulose without any significant chemical modifications. This finding was made in comparison with the peaks typically found in commercial cellulose as seen in table 2

Table 3.2: Major FTIR absorption bands in commercial cellulose (Al-Awa et al., 2023)

Wavenumber (cm⁻¹)	Functional Group	Description
~3200-3600	O-H stretching	Broad peak due to hydroxyl groups involved in hydrogen bonding.
~2800-3000	C-H stretching	Peak corresponding to the C-H bonds in CH ₂ and CH ₃ groups.
~1730 (if present)	C=O stretching (optional)	Small peak from carbonyl groups (if cellulose is modified, e.g., acetylated).
~1420-1480	C-H bending	vibrations of the methylene groups in cellulose.
~1200-1150	C-O-C stretching	Glycosidic bond between glucose units.
~1000-1150	C-O stretching	Strong peaks related to hydroxyl and glycosidic linkages.
~900	β-glycosidic linkage	Specific to β-glycosidic bonds in cellulose.

Comparison to Literature

The observed FTIR spectrum of the commercial cellulose sample is consistent with typical FTIR spectra of untreated cellulose reported in the literature. For example, the broad O-H stretching peak around 3300 cm⁻¹ and the strong C-O stretching bands in the range of 1000-1100 cm⁻¹ are well-documented in the analysis of cellulose (Al-Awa et al.,2023).

The lack of additional peaks indicates that the sample has not undergone significant chemical modification, such as acetylation or esterification, which would otherwise introduce additional carbonyl (C=O) stretching bands around 1700 cm^{-1} .

3.1.2 The scanning electron microscopy (SEM)

The Scanning Electron Microscopy (SEM) images provide a detailed visualization of the morphological characteristics of commercial cellulose at various magnifications (500x, 1000x, and 2000x). These images reveal key features of cellulose fibers, which can significantly influence its behavior in different applications, especially in composite materials, filtration, and paper production.

Figure 3



Figure 3.3: SEM image of the sample of cellulose extracted from rattail grass at magnification 500

At 500x magnification, the image highlights a densely entangled network of cellulose fibers. The fibers are observed to have varying diameters, with some fibers appearing more aligned than others. The loose structure and high porosity are typical of commercial cellulose, making it suitable for use in absorbent materials and reinforcing fillers in composites. The porous nature of the structure indicates that cellulose can trap air or other particles within the material, which may also

contribute to its high surface area and potential for chemical reactions, such as in filtration or catalysis.

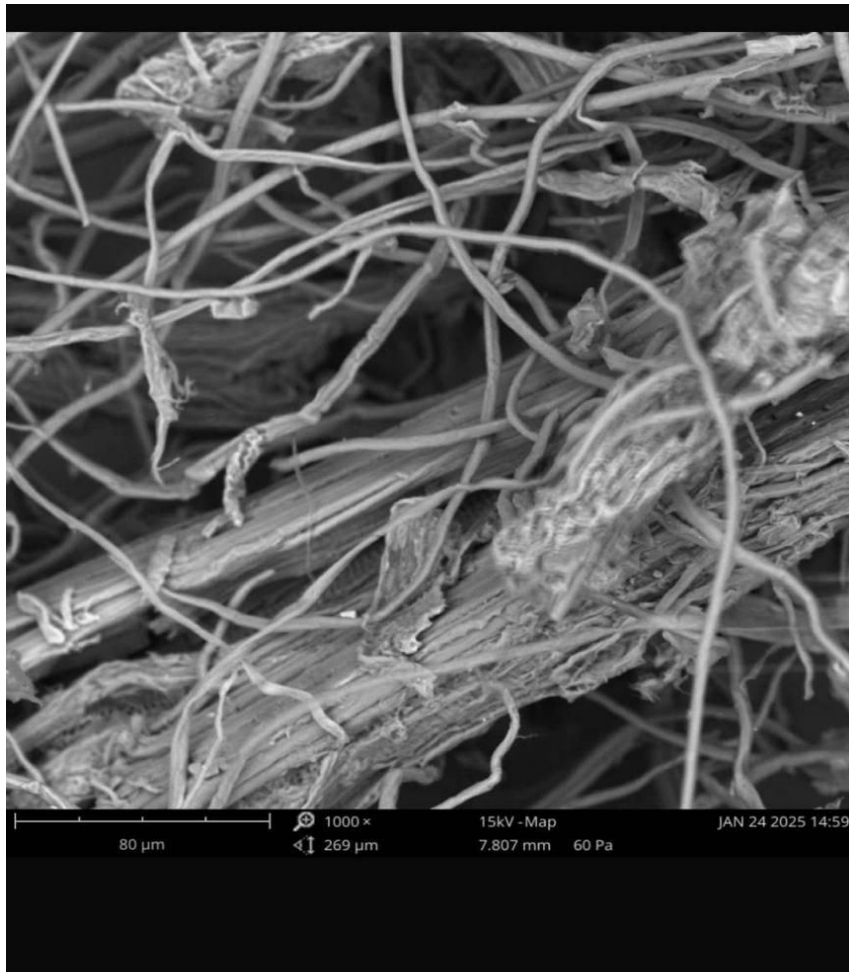


Figure 3.4: SEM image of the sample of cellulose extracted from rat tail grass at magnification 1000

In the 1000x magnification image, the finer details of the cellulose fibers become more apparent. The fiber surface appears to have some roughness, possibly due to mechanical processing or natural imperfections. This roughness can enhance the bonding or adhesion between the cellulose fibers and other components in composite materials, improving the mechanical properties. Additionally, there are

visible fibrillation effects, where fibers appear to split into smaller fibrils. Fibrillation is a critical feature in cellulose fibers, as it can increase the fiber surface area, thus enhancing their potential for bonding or interactions with other substances.

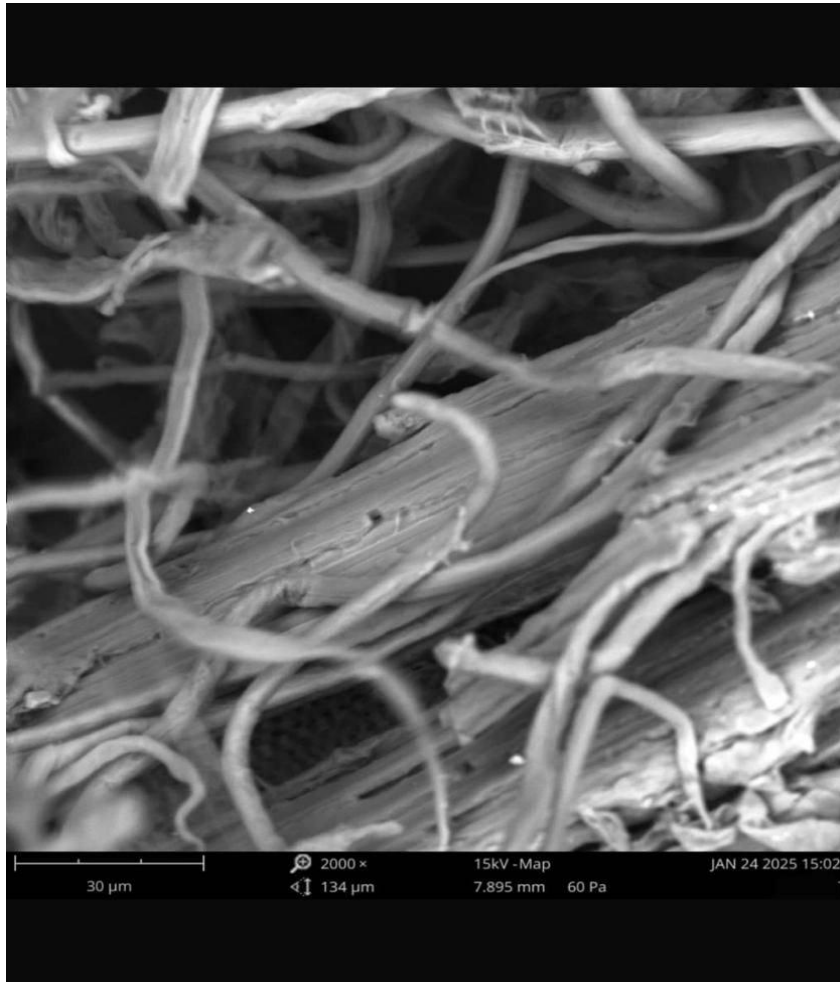


Figure 3.5: SEM image of the sample of cellulose extracted from rat tail grass at a magnification of 2000

The 2000x magnification image provides a closer examination of the individual fibers. The fibrils are distinctly visible, and their intertwined structure demonstrates

the hierarchical organization of cellulose at the microscopic level. This complex structure, with both primary fibers and smaller fibrils, contributes to cellulose's high tensile strength and durability, properties that are highly desirable in both industrial applications and biodegradable products. Furthermore, the image shows how tightly bound the fibers are to one another, which could be advantageous in creating materials with good mechanical reinforcement.

Overall, the SEM analysis of the fibers shows the intricate and highly interwoven structure that defines their physical properties. The high porosity, fibrillation, and rough surface topology observed in these images suggest that cellulose would be highly effective as a reinforcing agent in composites, as well as a functional material in filtration and absorbent products. These morphological characteristics directly influence cellulose's mechanical and chemical behavior, making it a versatile material for various industrial and environmental applications.

3.2 Yield of cellulose acetate from the cellulose derived from Rat tail grass

Formula:

$$\text{Percentage Yield} = (\text{Theoretical Yield} / \text{actual Yield}) \times 100$$

Where:

$$\text{Actual Yield} = 7 \text{ grams (amount of cellulose acetate obtained)}$$

$$\text{Theoretical Yield} = 10 \text{ grams (initial amount of cellulose used)}$$

$$\text{Percentage Yield} = (10\text{grams}/7 \text{ grams}) \times 100$$

$$\text{Percentage Yield} = 0.7 \times 100 = 70\%$$

Thus, the percentage yield of cellulose acetate from cellulose is 70%.

3.3.0 Results on the characterization done on the sample cellulose acetate

3.3.1 Fourier transform infrared spectroscopy (FTIR) analysis of the sample of cellulose acetate derived from rattail grass

Infrared (IR) spectroscopy is a widely used technique for the characterization of organic compounds, particularly in identifying functional groups within a molecule.

In this study, the IR spectrum of a sample labeled "SAMPLE OF RAT TAIL GRASS" was analyzed and compared to known spectral features of cellulose acetate, a widely used biopolymer derived from cellulose.

The IR spectrum of the sample was obtained using an Agilent Technologies instrument in transmittance mode. The scan parameters included a resolution of 8, with 32 sample scans and 16 background scans, covering a spectral range from 4000 to 650 cm^{-1} . The analysis employed the Happ-Genzel apodization function to improve the resolution of spectral features.

The FTIR spectrum of the sample displayed several characteristic peaks, which are consistent with the structure of commercial cellulose acetate. The key absorption bands and their corresponding functional groups are summarized in Table 3.

Table 3.3: This table summarizes the comparison between the Rat tail grass sample spectrum and commercial cellulose acetate spectral features, providing a clear view of similarities and functional group assignments.

Spectral Feature	Commercial Cellulose Acetate (Expected Range)	Rattail Grass Sample (Observed Peaks)	Functional Group	Interpretation
C=O Stretching (Ester Group)	~1740 cm ⁻¹	1736 cm ⁻¹	Ester carbonyl (C=O)	Presence of ester groups, possibly cellulose derivatives.
C-O Stretching (Acetate Group)	~1235 cm ⁻¹	1256 cm ⁻¹	Acetate C-O bond	Suggests C-O bonds in ester or acetate functional groups.
C-O Stretching (Acetate Group)	~1030 cm ⁻¹	1034 cm ⁻¹	Acetate C-O bond	Correlates with C-O vibrations, indicating ester linkages.
O-H Stretching (Hydroxyl Group)	~3400 cm ⁻¹	Broad peak observed around 3400 cm ⁻¹	O-H (hydroxyl) bonds	Weaker absorption suggests fewer free hydroxyl groups.
C-H Stretching (Alkyl Groups)	~2900 cm ⁻¹	Similar absorption observed around 2900 cm ⁻¹	Alkyl (CH) stretching	Indicates presence of alkyl chains, common in organic molecules.

Interpretation of the table 3

1. C=O Stretching (Carbonyl Group): Cellulose acetate typically exhibits a strong absorption band at around 1740 cm⁻¹ due to the ester carbonyl (C=O) stretching

vibration. In the spectrum of the Rattail grass sample, a prominent peak was observed near 1736 cm^{-1} , which is within the expected range for the C=O stretching vibration. This suggests the presence of ester groups in the sample, possibly indicating the existence of cellulose derivatives or other ester-containing compounds in the plant material.

2. C-O Stretching (Acetate Group): Cellulose acetate is characterized by C-O stretching vibrations in the region of 1235 cm^{-1} and 1030 cm^{-1} , corresponding to the acetate functional groups. The grass sample exhibited peaks at 1256 cm^{-1} and 1034 cm^{-1} , which are in close agreement with these cellulose acetate peaks. These bands suggest that the sample may contain compounds with C-O bonds, such as those found in acetate groups or similar ester linkages.

3. O-H Stretching (Hydroxyl Group): Cellulose acetate, derived from cellulose, retains hydroxyl groups, which contribute to broad O-H stretching absorptions typically observed around 3400 cm^{-1} . While the spectrum of the grass sample showed broad absorption in this region, the intensity was less pronounced compared to pure cellulose acetate, which may indicate a lower concentration of free hydroxyl groups or the presence of hydrogen-bonding effects.

4. C-H Stretching (Alkyl Groups): A characteristic absorption of alkyl (CH) stretching in cellulose acetate is typically observed around 2900 cm^{-1} . The grass sample spectrum displayed similar absorbance in this region, suggesting the presence of alkyl chains, which are common in organic compounds, including those derived from plant material.

Conclusion

The infrared spectral analysis of the Rattail grass sample reveals key similarities to cellulose acetate, particularly in the ester and C-O stretching regions, indicating the presence of ester linkages and cellulose-like structures. Peaks corresponding to C=O and C-O bonds, as well as alkyl chain vibrations, suggest that the sample contains components structurally related to cellulose derivatives or esters commonly found in plant materials.

However, the weaker O-H stretching peak suggests fewer free hydroxyl groups compared to pure cellulose acetate, potentially due to partial acetylation or hydrogen bonding in the sample. These findings support the hypothesis that Rattail grass contains cellulose-like compounds

In summary, the study demonstrates the utility of IR spectroscopy in elucidating the chemical composition of natural plant fibers, offering a preliminary insight into the structure of Rattail grass. This analysis serves as a foundation for further research into the potential applications of the material, especially in industries where cellulose-based products are of interest.

3.3.2 Solubility of Cellulose Acetate in Ethanol

The experiment was conducted to evaluate the solubility of the sample of cellulose acetate in ethanol at room temperature. The cellulose acetate sample (10 grams) was placed in 10 mL of ethanol and stirred for 24 hours. The results of the experiment are summarized as follows:

Table 3.4: Tabular representation of the result of solubility experiment

Time (hrs)	Observation
0	Cellulose acetate sample remained solid, no dissolution.
1	No noticeable dissolution.
3	Minor swelling of cellulose acetate.
6	Slight turbidity, indicating minimal dissolution.
12	Sample remained mostly undissolved, with light cloudiness in the solution.
24	Sample largely undissolved, small amount of gel-like residue.

3.4 Discussion and Interpretation

The results indicate that cellulose acetate sample exhibits very low solubility in ethanol at room temperature. Despite continuous stirring, the majority of the cellulose acetate sample remained undissolved after 24 hours, with only slight swelling and minor turbidity observed. This outcome is consistent with the well-documented fact that cellulose acetate, particularly with a higher degree of substitution (acetylation), tends to be insoluble in ethanol due to the polar nature of the solvent and the semi-polar nature of the polymer.

In ethanol, a polar solvent, the interaction with cellulose acetate's polymer chains is limited. The acetate groups attached to the cellulose backbone make the polymer more hydrophobic, reducing its ability to form hydrogen bonds with ethanol. As a result, only minimal swelling of the sample occurs, and little dissolution is observed, confirming ethanol's ineffectiveness as a solvent for cellulose acetate under these conditions.

The slight turbidity and gel-like residue observed at the end of the experiment may suggest partial surface dissolution of cellulose acetate sample or the formation of a hydrated gel-like network. However, the undissolved bulk of the sample indicates that ethanol alone is insufficient to break down the polymer chains, indicating the presence of a modest to high degree of substitution.

Conclusion

The experiment confirms that cellulose acetate is insoluble in ethanol at room temperature, with only minor swelling and no significant dissolution over a 24-hour period. This low solubility can be attributed to the degree of substitution (DS) of the acetate groups on the cellulose backbone. As the degree of substitution increases, the number of hydroxyl ($-OH$) groups on the cellulose chain is replaced by acetyl groups ($-OCOCH_3$), which reduces the polymer's ability to interact with polar solvents like ethanol through hydrogen bonding. This finding indicates the presence of cellulose acetate with modest to high degree of substitution

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