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EXTRACTION OF CELLULOSE FROM COTTON STALKS AND ITS COMPARATIVE FTIR ANALYSIS

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Abstract: This scientific study investigates the infrared (IR) spectral analysis of cellulose isolated from cotton stalks after treatment with alkali and hydrogen peroxide (H_2O_2) solutions of different concentrations. The main purpose of the research is to determine the physicochemical properties of cellulose obtained from plant raw materials and to assess the structural changes that occur during processing. Cotton stalks are an inexpensive and efficient locally available raw material, and cellulose isolated from them can be widely used in the production of paper, biopolymers, medical materials, and other environmentally friendly products.

Keywords: cellulose, physicochemical properties, IR spectroscopy, functional groups.

Introduction

Today, increasing attention is being paid to the rational use of renewable natural resources and to the production of environmentally friendly and biotechnological products. From this perspective, residues of annual plants, particularly cotton stalks, are of considerable importance, because valuable compounds for industry, including cellulose, can be isolated from them.

Cellulose is one of the most widespread natural polymers and is biodegradable and environmentally safe. It is widely used in the production of paper, textiles, biomaterials, bioplastics, and medicinal products. The use of rapidly renewable plant resources instead of traditional sources such as wood helps conserve resources and reduce waste. This study aims to evaluate the practical potential of cellulose by developing a method for isolating it from annual cotton stalks and studying the physicochemical properties of the obtained product.

At present, in order to establish modern high-technology manufacturing sectors in industry, broader opportunities should be created for the development of small business and private entrepreneurship in areas such as pharmacology and pharmaceuticals, information and communication systems, biotechnology, alternative energy, tourism, and other fields.

Therefore, in the development of our country's economy, we, as young students, should devote our knowledge, experience, strength, and capabilities alongside everyone else. For this purpose, we should mobilize our knowledge and efforts and work effectively for the development of the pharmaceutical industry, which is one of the important sectors of the national economy.

From this point of view, to further develop the pharmaceutical sector in our Republic, it is necessary to identify, study, and introduce medicinal products that are environmentally clean and natural.

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Cellulose and its role in industry and science. Cellulose is the main structural component of plant cell walls and belongs to the group of complex carbohydrates (polysaccharides). Its molecule consists of a very long chain of β-D-glucopyranose rings. The glucose units are linked by β-1,4-glycosidic bonds, which give cellulose a strong and insoluble structure. Its chemical formula is $(C_6H_{10}O_5)_n$. It is a white fibrous substance, insoluble in water and common organic solvents, mechanically strong and flexible, and decomposes and burns at high temperatures. It occurs in large amounts in plant stems, leaves, seed coats, and wood (95–98% in cotton and 40–50% in wood). Some bacteria, for example Acetobacter xylinum, can also synthesize cellulose [10].

Cellulose is one of the most abundant natural polymers on Earth and is used as a major raw material in many production sectors:

a) Paper and cardboard production – The paper industry is the largest consumer of cellulose. It is obtained from wood pulp or cotton fibers and is used to manufacture writing, printing, and packaging materials [3].

b) Textile industry – Cotton fiber consists mainly of pure cellulose. Cellulose is chemically processed in the manufacture of artificial fibers such as viscose and acetate fibers [3].

c) Chemical industry – Nitrocellulose is used in explosives and paints and coatings; cellulose acetate is used in photographic films and plastic products; carboxymethylcellulose is used as a viscosity-enhancing agent in foods and pharmaceutical products [4].

d) Food industry – Cellulose is used as a thickener and stabilizer (E460), and as a calorie-free filler in dietary products.

e) Packaging and biopolymers – Cellulose-based biodegradable films do not harm the environment.

Cellulose is important not only in industry but also in scientific research.

a) Materials science – Nanocellulose (nanocrystalline cellulose, NCC) has high strength and is used to create composite materials. It is a raw material for new lightweight but durable structures.

b) Biomedicine – Cellulose is used in bioactive wound dressings and modified cellulose can serve as a carrier for drug delivery [5].

Cellulose is composed of glucose molecule residues, and during acid hydrolysis the following reaction is given:

$$(C_6H_{10}O_5)_n + nH_2O \rightarrow nC_6H_{12}O_6$$

Cellulose consists of long fibers containing approximately 300–2500 glucose residues and has no lateral branching. Numerous hydrogen bonds connect the chains to one another and provide strong mechanical properties [2].

As a result of sulfuric acid hydrolysis, cellulose is stained blue, whereas iodine alone stains it brown. In addition to cellulose, plant cells contain several other carbohydrates collectively known as

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hemicellulose. Hemicellulose can be separated from the material using 1% hydrochloric acid or sulfuric acid [2].

Research object and methodology. The object of the study was the stalk of the cotton plant growing in Namangan Region, and the subject of the study was cellulose.

Preparation of plant samples. Cotton stalks growing in Kosonsoy District of Namangan Region were collected and ground to a powder.

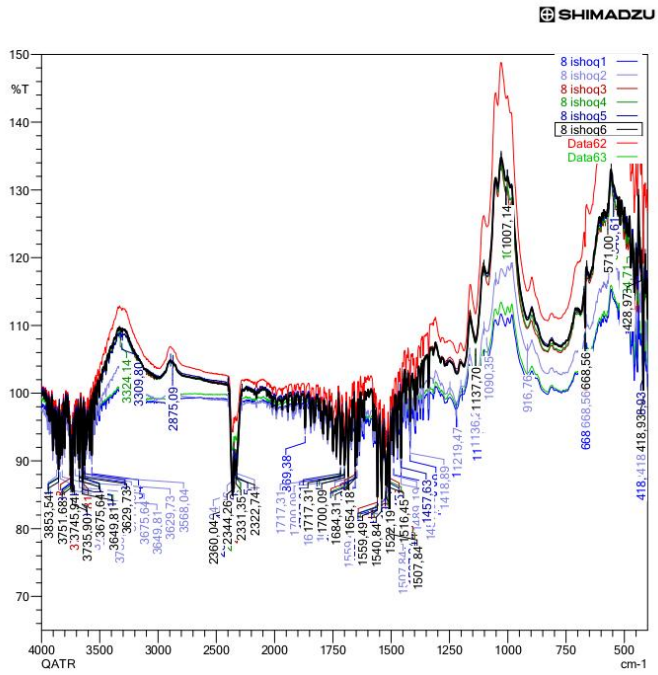
Stages of cellulose isolation. An alkaline method was used for cellulose isolation. The cotton stalks were crushed, and 200 g of the material was taken. The obtained 200 g of powder was boiled in water for 6 hours. After boiling, the mass difference was determined:

200 − 167.72 = 32.28 g mass difference

From 167.72 g, 150 g was taken and divided equally into three portions of 50 g. Each portion was boiled for 3 hours at 90°C in 5%, 7%, and 8% NaOH solutions. Bleaching was then carried out using 5%, 10%, and 15% hydrogen peroxide solutions.

The results showed that alkaline treatment removed the major portion of lignin and other impurities. However, the bleaching process was not sufficiently effective, which may have been related to residual lignin or a low hydrogen peroxide concentration. The powder became light yellow in color.

When the bleached samples were subjected to IR spectroscopy, the presence of substances containing alkyne, aldehyde, amide, and other functional groups was detected as additional components.



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Figure 1. Comparative IR spectra of cellulose samples treated with alkali and H_2O_2 solutions of different concentrations.

The figure above compares the bleaching of samples in 10%, 15%, and 30% H_2O_2 solutions and in 7%, 8%, and 15% alkali solutions. The sample treated with 15% alkali and bleached in 30% H_2O_2 produced better peaks than the other samples.

Conclusion

During the experiment, cellulose samples were treated with NaOH and H_2O_2 solutions of different concentrations. IR spectroscopy recorded the vibrational frequencies of functional groups, changes in hydroxyl groups, and the strengthening or weakening of C–H, C–O, and C=O bonds.

The analysis showed that as the alkali concentration increased, the amount of inorganic impurities and lignin in the cellulose structure decreased. Treatment with H_2O_2 enhanced the bleaching of cellulose and improved its quality indicators. This study contributes to improving cellulose-based biotechnological processes and expanding the possibilities for efficient processing of local raw materials.

The physicochemical characteristics of the isolated cellulose were determined. Local annual plants are a source of cellulose. However, compared with other annual plants, cotton stalks contain a lower amount of cellulose.

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