DEVELOPMENT OF A TECHNOLOGY FOR PRODUCING MOISTURE- AND BACTERIA-RESISTANT PAPER FROM PAULOWNIA STEMS GROWN UNDER THE CLIMATIC CONDITIONS OF SURKHANDARYA

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Abstract The development of environmentally friendly and functional paper materials from locally available renewable biomass is an important research direction in the pulp and paper industry. This study focuses on the development of a technology for producing moisture- and bacteria-resistant paper from the stems of Paulownia trees grown under the climatic conditions of the Surkhandarya region of Uzbekistan.

Keywords: Paulownia, cellulose, paper, moisture resistance, antibacterial paper, hydrophobic modification, lignin, hemicellulose, alkaline pulping, Surkhandarya, renewable biomass, functional materials.

1. Introduction

The increasing demand for environmentally friendly and functional materials has stimulated significant interest in the development of new cellulose-based products. Paper and cellulose materials are widely used in packaging, food processing, agriculture, medicine, sanitary products and various industrial applications. However, conventional paper has several limitations, particularly its high affinity for water and susceptibility to microbial contamination under humid conditions.

Cellulose contains a large number of hydroxyl groups capable of forming hydrogen bonds with water molecules. As a result, untreated paper readily absorbs moisture, which can cause swelling, loss of mechanical strength, deformation and deterioration of its functional properties. In addition, humid cellulose-containing materials can provide favorable conditions for the growth of microorganisms.

Therefore, the development of paper with improved moisture resistance and antibacterial properties is of considerable scientific and practical interest.

Uzbekistan possesses significant renewable plant resources that can potentially be used as alternative raw materials for cellulose production. The use of locally available biomass can reduce the dependence of the pulp and paper industry on imported raw materials and create opportunities for the development of new domestic technologies.

The main objective of this research is to develop a technological approach for producing paper from Paulownia stems with enhanced **moisture resistance and antibacterial properties**. Paulownia stems cultivated under the climatic conditions of the Surkhandarya region were selected as the main raw material.

Before chemical processing, the stems were subjected to preliminary mechanical treatment. Foreign materials, bark residues and other impurities were removed. The stems were then cut and mechanically reduced to a suitable particle size for subsequent chemical treatment. Alkaline pulping was selected as one of the principal methods for separating

cellulose from Paulownia biomass. Lignocellulosic biomass consists mainly of cellulose, hemicellulose and lignin. Cellulose forms the structural framework of the plant cell wall, while lignin acts as a complex binding matrix. During alkaline treatment, a portion of lignin and hemicellulose is solubilized, resulting in a cellulose-enriched fibrous material.

After pulping, the fibrous material is thoroughly washed to remove residual alkali and dissolved organic substances. Further purification and, where necessary, bleaching can be applied to improve the optical and chemical properties of the cellulose.

2. Formation of Cellulose-Based Paper

Following purification, the cellulose fibers are subjected to mechanical refining. Refining increases the specific surface area of fibers and promotes fibrillation. These structural changes improve fiber-to-fiber bonding during paper formation.

The formation of the paper sheet involves the preparation of an aqueous fiber suspension, deposition of the fibers onto a forming surface, removal of excess water, pressing and drying.

The strength of cellulose-based paper is largely determined by the interaction between individual fibers. Hydrogen bonding between hydroxyl groups on adjacent cellulose surfaces plays a significant role in the formation of the paper network.

However, increasing the degree of fiber refining without optimization may adversely affect drainage and processing efficiency. Therefore, the refining degree must be selected according to the desired balance between mechanical strength, porosity and moisture resistance.

3. Development of Moisture-Resistant Paper

One of the principal objectives of this research is to reduce the hydrophilic character of cellulose-based paper.

The hydroxyl groups present in cellulose interact strongly with water. Consequently, untreated cellulose paper can rapidly absorb water and lose its mechanical integrity under wet conditions.

To overcome this limitation, hydrophobic modification can be introduced into the paper manufacturing process.

4. Development of Bacteria-Resistant Paper

The second major functional property targeted in this research is resistance to bacterial contamination.

Cellulose-based materials exposed to moisture may become favorable substrates for microbial growth. Therefore, the combination of moisture resistance with antibacterial functionality is scientifically important.

The antibacterial functionality can be introduced through incorporation of an appropriate functional component into the paper matrix or by applying an antibacterial surface treatment.

The selected antibacterial component should satisfy several requirements:

- compatibility with cellulose fibers;
- sufficient stability within the paper matrix;
- resistance to leaching under normal use conditions;
- effectiveness against the target microorganisms;
- minimal negative effect on paper strength;
- environmental and toxicological safety.

The antibacterial effect should be experimentally verified under controlled laboratory conditions. Modified paper samples should be compared with untreated control samples.

The evaluation can include:

- bacterial growth inhibition;
- reduction in viable bacterial count;
- inhibition-zone measurements where applicable;
- antibacterial activity after moisture exposure;
- durability of the antibacterial effect.

It is important to distinguish between general **bacterial resistance** and a scientifically verified **antibacterial effect**. Claims concerning antibacterial or antimicrobial properties of the final product should be supported by appropriate standardized microbiological testing.

5. Optimization of the Technological Parameters

The performance of the developed paper depends on the interaction of several technological factors. Therefore, optimization of the process parameters is essential.

The principal factors to be investigated are presented in Table 1.

Table 1. Main technological parameters affecting the properties of Paulownia-based functional paper

No.	Technological parameter	Main effect
1	NaOH concentration	Delignification and cellulose yield
2	Pulping temperature	Rate of chemical delignification
3	Pulping time	Cellulose yield and polymer integrity
4	Refining degree	Fiber bonding and paper strength
5	Hydrophobic agent concentration	Water resistance
6	Antibacterial component concentration	Bacterial resistance
7	Drying temperature	Structure and mechanical properties
8	Surface coating level	Surface hydrophobicity

Optimization should consider several properties simultaneously.

For example, increasing the concentration of a hydrophobic component may improve water resistance but may also reduce inter-fiber bonding if the treatment is excessive. Similarly, intensive alkaline treatment can improve delignification but may reduce the degree of polymerization of cellulose.

Thus, the optimal technology should provide a balanced combination of:

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