

Eco-Friendly Waterproof Materials from Natural Plants: Applications and Performance Comparison of Reed-Based and Palm Leaf-Based Materials

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Abstract—In the context of growing environmental concerns and the need for sustainable alternatives to conventional synthetic waterproof materials, this study explores the use of natural plant-based waterproof materials through a literature review and case analysis. The paper employs reed- and palm-leaf-based materials as eco-friendly waterproof materials to explore their chemical composition, waterproof performance, and mechanistic differences. Palm leaf-based materials depend on surface wax extraction to prepare hydrophobic coatings, with the wax components limiting water-matrix interactions, making them applicable to low-strength, moisture-resistant scenarios. In contrast, reed-based materials primarily rely on retaining their inherent multi-level hydrophobic structure. The structure makes reed-based materials suitable for applications requiring mechanical strength and structural stability. This research further proposes enhancement strategies, such as using natural adhesives to fill pores and diluted natural resins to surface-modify. This study provides a theoretical basis and practical reference for the targeted development and sustainable use of plant-based waterproofing materials.

Keywords—natural plant extract, waterproof material, reed-based material, palm leaf-based material, eco-friendly material, hydrophobic mechanism

I. INTRODUCTION

Waterproof materials are indispensable core materials in daily life and production, and their importance permeates various fields. However, most commonly used waterproof materials on the market are synthetic, which emit harmful gases during production, are difficult to degrade after use, and are non-renewable, leading to environmental pollution and resource waste. Therefore, developing and promoting environmentally friendly, renewable, and sustainable alternatives has become an urgent necessity.

Among numerous sustainable alternatives, plant-based materials stand out due to their significant advantages of being green, renewable, and pollution-free, making them a focal point of research in the current waterproof material field. Most plant-based materials are derived from natural plants, which are widely available and recyclable, imposing no additional burden on the environment and aligning well with contemporary environmental protection principles [1]. Currently, researchers have prepared a waterproof and oil-repellent agent containing an extract of *Ampelopsis grossedentata* obtained by pure water extraction without any additives [2].

However, the diversity of plant-based materials also presents considerable challenges. Different types of plant raw materials vary in their ground distribution and possess distinct microstructures and chemical compositions. These

variations directly result in substantial discrepancies in the final material's waterproof performance, mechanical strength, and durability, complicating standardized development and scalable application.

To address this gap, this study conducts a literature review and a comparative case analysis of two different raw materials: reed and palm leaf. It systematically clarifies their differences in waterproofing principle, processing technologies, and product performance. The paper aims to provide a clearer framework for material selection and process design, offering practical references for application in waterproof materials.

II. RELATED WORK

A. Theoretical Framework

There are two common methods of preparing plant-derived waterproof materials. The first is the functional component extraction method, used to achieve waterproofing by extracting plant surface wax, a dominant type. Palm leaf is a typical representative of this kind of raw material, and its surface wax can be extracted by a simple solvent to prepare a hydrophobic coating.

The second is to retain and optimize the inherent multistage hydrophobic structure of plants without extracting functional components. For natural extract waterproof materials, the superhydrophobicity of the plant surface is crucial. There are many superhydrophobic plant leaves in nature. When water droplets hit these surfaces, they are prone to sputter and rebound [3]. The core of the natural waterproofing performance of plant-based waterproof materials lies in the direct correlation between plant surface waxes and hydrophobicity. The hydrophobicity of plant surfaces is not a natural "characteristic" but is conferred by the wax secreted from the surface. At the same time, plant cellulose has high strength and stability, making it suitable as a structural component in waterproof materials. Through cross-linking, grafting, and other modification methods, the mechanical properties and waterproof durability of the materials can be further improved [4].

B. Research Progress on Plant-Based Waterproof Materials

Carnauba wax, a typical plant-derived wax similar to palm leaf surface wax. Studies have shown that adding it to biopolymer films significantly enhances hydrophobicity. Their unique fatty acid esters and other components can limit the interaction between starch and water. Generally, wax's intrinsic hydrophobicity reduces the WVP value when its

water-repellent effect is stronger than the decrease in matrix cohesion. Notably, nanoemulsion films exhibit better barrier properties than microemulsion systems, primarily due to wax-starch interactions that restrict hydroxyl group accessibility and create tortuous diffusion paths. Nevertheless, structural defects may partially counteract these advantages. The increased contact angle, correlated with wax content but independent of emulsion droplet size, verifies carnauba wax's effectiveness in fabricating moisture-resistant food packaging to extend food shelf life [5]. The other project utilizes plant fibers and fly ash as the primary raw materials, employing material grafting technology and semi-interpenetrating polymer network process to prepare high-strength waterproof composite materials. Another research direction uses plant fibers and fly ash as primary raw materials, adopting material grafting technology and semi-interpenetrating polymer network processes to prepare high-strength waterproof composite materials [6]. This composite strategy provides a reference for reed fiber reinforcement.

All in all, the current research lacks a comparison of both waterproof materials. Therefore, this paper will use two typical materials to systematically analyze the extraction methods and the challenges [5].

III. PREPARATION AND PERFORMANCE CHARACTERIZATION OF PALM LEAF AND REED-BASED WATERPROOF MATERIALS

A. Extraction Technology of Palm Leaf Wax

At present, two processes are commonly used in industry: solvent extraction and melting extraction. The extraction of palm leaf wax is the core step for its use in waterproof applications. The extraction of Korla fragrant pear fruit epidermis wax offers a feasible alternative to palm leaf wax [7].

1) Solvent extraction

Solvent extraction is the most widely used process, and anhydrous ethanol is often used as the extraction agent. During the operation, the palm leaves are pretreated, the veins are removed, washed and dried, and cut into small pieces. Then the sample is mixed with the solvent in the appropriate proportion, heated in a water bath, and stirred to promote the dissolution of wax. After filtering and removing the residue, the crude wax extract is volatilized by the solvent [7]. The process has high extraction efficiency, fully enriches the wax components on the surface of palm leaves, and uses a mild extraction temperature that will not damage the wax's hydrophobic activity, making it suitable for small-scale extraction in the laboratory and for basic research.

2) Melting Extraction

The melting method is another commonly used extraction process. The core is to melt and separate the wax on the surface of palm leaves by heating, which is similar to the idea of thermal separation and extraction of Korla Fragrant Pear skin wax. The pretreatment steps are the same as the solvent extraction method. In the subsequent process, the palm leaf sample is heated directly to a suitable temperature without the addition of organic solvents. After the wax melts, the wax is separated by centrifugation or filtration [7]. The

advantages of this process are simple operation, no organic solvent pollution, low cost, and suitability for large-scale batch extraction. However, the extraction efficiency is lower than that of the solvent extraction method. Improper temperature control may cause wax oxidation, degrade hydrophobic components, and reduce waterproof performance. In addition, it is difficult to extract a small amount of wax attached to palm leaves.

B. Extraction Technology of Reed

1) Raw material pretreatment

The use of reed-based waterproof materials has diversified characteristics. The core relies on its natural multi-level hydrophobic structure without extracting wax and optimizes performance through different processing methods, which are mainly divided into two common use forms: overall use and fiber reinforcement.

During raw material pretreatment, the stems and leaves of fresh reed should be washed first, and surface moisture should be removed to prevent impurities from affecting processing. Direct cutting is required to avoid friction damage to the wax layer and the nano-hydrophobic surface. For reed stems, the outer epidermis can be gently scraped off and cut into pieces to retain the wax layer on the epidermis and the stem's internal porous structure. At the same time, through low-temperature drying treatment, the hydrophobic activity of the wax layer can be retained to the greatest extent, laying the foundation for subsequent processing [8].

2) Integral use

In terms of integral use, the natural structure of the reed is retained, and its waterproof performance is optimized through physical processing methods. The core processing technology is mainly physical pressing. The pretreated and dried reed samples are placed back into the mold for cold pressing and shaping, and then formed into dense plates or rolls [8]. Physical pressing does not require additional chemical reagents, thereby avoiding damage to the reed's natural multi-level hydrophobic structure, reducing the fiber gap, and improving the material's structural stability and mechanical strength. Previous studies have confirmed that cold-pressing treatment can effectively improve the density of reed materials, reduce water penetration channels, significantly enhance their waterproof durability, and be environmentally friendly.

3) Fiber reinforcement

Fiber reinforcement is another important application form of reed-based waterproof materials [6]. The pretreated and dried reed stems and leaves are crushed and screened to obtain reed fibers (a particle size of 40-60 mesh) by a fiber mill. The reed fibers can be mixed with inorganic substrates to form a basic composite system. A small amount of natural adhesives is added to improve the interfacial bonding performance in common. After hot pressing usually at 60-80°C and 3-5 MPa, the material is demolded after shaping to obtain the reed fiber-reinforced composite waterproof material.

IV. COMPREHENSIVE COMPARATIVE ANALYSIS

A. Comparison of Two Preparation Methods

According to the table 1, the extraction path of palm leaves mainly focuses on the separation and utilization of wax, relies on solvent extraction or the melting method to extract the surface wax, and then applies the wax to the preparation of waterproof coatings for various substrates, which is suitable for low-strength moisture-proof scenes with high requirements for substrate adaptability. The processing path for reed prioritizes the preservation and optimization of its natural structure, without extracting functional components. Through simple processes such as physical pressing or fiber reinforcement, it can play its natural hydrophobic performance, which is more in line with the requirements of environmental protection and low-cost large-scale application. The difference between the two stems from their different reliance on the core factors for waterproofing, which also determines their respective application boundaries and provides a clear reference for subsequent targeted research, development, and scene selection of plant-based waterproof materials.

Table 1. Comparison of preparation methods between palm leaf and reed-based waterproof materials [6–9]

Comparison Dimension	Palm Leaf (Wax Extraction Path)	Reed (Natural Structure Optimization Path)
Core Processing Method	Extract wax by solvent extraction or melting method, then prepare coating	Physical pressing (integral use), fiber reinforcement (composite processing)
Core Dependence for Waterproofing	Extracted surface wax, with hydrophobic groups forming a hydrophobic interface	Natural multi-level hydrophobic structure (wax layer and porous network)
Processing Complexity	High, requiring wax extraction, purification and coating preparation	Low, no extraction required, only pretreatment and physical processing
Advantages	Extracted wax has strong substrate adaptability; targeted hydrophobicity	Environmentally friendly processing with low cost; mechanical strength optimizable by compounding
Shortcomings	High pollution risk of solvent extraction, poor wear resistance of wax	Loose natural structure, limited weather resistance of pure reed materials
Suitable Scenarios	Disposable food packaging, simple moisture-proof coatings	Agricultural water retention, building interior wall moisture-proof, composite waterproof material substrate

B. Challenges of Palm Leaf and Reed-Based Waterproof Materials

The shortcomings of palm leaf are from the wax extraction process and the wax coating characteristics. The wax coating has poor wear resistance and low bonding strength with substrates; solvent extraction has the risk of organic solvent pollution, while improper temperature control in melting extraction can easily cause wax oxidation and hydrophobic performance degradation. In addition, the surface wax layer is prone to aging and falling off in a high-temperature and high-humidity environment, which reduces long-term waterproof effectiveness.

For reed-based waterproof materials, the deficiencies are derived from their inherent structural properties. The loose arrangement of internal fibers results in insufficient mechanical strength, making the materials easily damaged by external forces and with limited weather resistance. The surface wax layer is sensitive to temperature and humidity changes, which impairs its hydrophobic durability.

C. Modification Strategies

For palm leaf applications, the short board is determined by wax properties: soft texture, weak adhesion with the substrate, and insufficient wear resistance and stability. Three types of simple process optimization can be adopted: adding natural binders such as starch paste to enhance the adhesion, setting and stabilizing the wax layer at 40–60°C, doping plant fibers to improve the wear resistance, taking into account the feasibility and practicability. It is necessary to control the process temperature and composition ratio to avoid damaging the hydrophobic activity of wax.

In comparison, for reed-based waterproof materials, a natural binder is used to fill fiber pores and delay wax aging. Diluted natural resin is used for surface modification to form a protective film to strengthen weather resistance and wear resistance. As agricultural waste, reed resource utilization conforms to the concept of environmental protection.

V. CONCLUSION

This paper compares palm leaf and reed as plant-based waterproof materials in terms of waterproofing features, applications, and other characteristics. The two differ significantly. Palm leaf relies on surface wax, which is extractable with solvents or by melting, for hydrophobicity, and suits low-intensity moisture-proof scenarios. However, its poor wear resistance requires adhesive modification to offset application limits. Reed achieves waterproofing through its natural wax layer, combined with nanostructures that create synergistic superhydrophobicity, requiring no additional wax extraction and fitting fixed-shape moisture-proof scenarios. Its loose fiber structure may result in low mechanical strength, requiring pressure shaping to enhance structural stability and application feasibility.

This study has specific limitations. It is primarily based on secondary data from literature reviews and lacks in situ experimental validation or advanced fabrication process optimization. Subsequent investigations should prioritize empirical assessment of the hydrophobic performance and reinforcement strategies for both substrates, refine processing protocols to mitigate the poor abrasion resistance of palm leaf cuticular wax and the low tensile strength of reed fibers.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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