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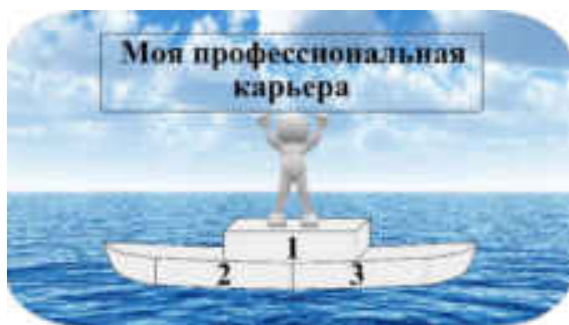


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**Международный научно-образовательный электронный журнал
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WATER-REPELLENT TREATMENTS FROM PLANT EXTRACTS»

Abstract

The growing environmental concerns associated with fluorinated and petroleum-derived hydrophobic finishing agents have intensified research into sustainable alternatives for textile and material surface protection. Conventional water-repellent treatments, particularly fluorocarbon-based finishes, demonstrate excellent repellency but are increasingly restricted because of persistence, toxicity, and bioaccumulation of perfluorinated compounds in ecosystems. In response, plant-derived hydrophobic compounds have emerged as promising renewable raw materials for the development of eco-friendly water-repellent systems. These bio-based treatments utilize naturally occurring waxes, fatty acids, terpenoids, polyphenols, and other hydrophobic phytochemicals extracted from botanical sources to generate protective coatings with reduced environmental impact. Recent studies show that natural waxes from rosemary, bark residues, and conifer biomass can produce water contact angles above 120°, while herb-based coatings can approach superhydrophobic behavior under optimized deposition conditions.

This article presents a detailed technological framework for obtaining eco-friendly water-repellent finishes from plant extracts, including extraction methodology, chemical modification, formulation strategies, substrate application, and physicochemical characterization. Particular attention is given to the interaction between plant-derived hydrophobic molecules and textile substrates, as well as to current limitations regarding durability, wash resistance, and industrial scalability.

1. Introduction

Water repellency in textile engineering is achieved through the reduction of surface free energy combined with the creation of hierarchical roughness that limits liquid penetration into porous structures. Traditional durable water repellent (DWR) systems rely predominantly on fluorinated polymers because of their extremely low critical surface tension. However, fluorochemical residues such as perfluorooctanoic acid and related compounds present serious ecological and toxicological concerns, prompting regulatory pressure for fluorine-free alternatives.

Plant-based hydrophobic systems offer an attractive alternative because many higher plants naturally synthesize epicuticular waxes that function as biological moisture barriers. These waxes consist primarily of long-chain alkanes, alcohols, esters, aldehydes, and fatty acids, which create microstructured surfaces responsible for natural hydrophobicity, as observed in lotus leaves, taro leaves, and other self-cleaning botanical surfaces. The biomimetic adaptation of these structures into textile finishing technology has become a rapidly developing research field.

The scientific rationale for using plant extracts lies in three major advantages:

- renewable origin,
- biodegradability,
- low toxicological burden.

Additionally, agricultural residues and plant-processing waste streams represent economically accessible feedstocks for industrial-scale extraction.

2. Selection of Plant Raw Materials for Hydrophobic Extraction

The efficiency of bio-based water-repellent treatment depends strongly on the chemical composition of the selected plant material. The most promising raw materials include:

2.1 Wax-Rich Plant Sources

- rosemary leaves (*Rosmarinus officinalis*)
- conifer needles and bark
- birch bark

- carnauba residues
- rice bran wax fractions

These materials contain high concentrations of long-chain esters and hydrocarbons responsible for hydrophobicity.

2.2 Polyphenol-Containing Sources

Certain extracts rich in tannins and phenolic compounds improve adhesion and film stability:

- pomegranate peel
- green tea residues
- spruce bark polyphenols

2.3 Essential Oil Sources

Terpene-rich oils contribute hydrophobicity and antimicrobial co-functionality:

- cinnamon oil
- clove oil
- eucalyptus oil

Recent studies indicate that combining wax fractions with phenolic fractions significantly improves both coating integrity and resistance to wetting.

3. Extraction Technology of Hydrophobic Plant Components

3.1 Solvent Extraction

The most widely applied method involves organic solvent extraction using:

- ethanol
- hexane
- petroleum ether
- acetone

The extraction process generally follows:

1. drying of plant biomass,
2. grinding to particle size below 1 mm,
3. Soxhlet or batch extraction,
4. solvent evaporation,

5. purification of wax fraction.

Hexane provides high wax recovery but presents environmental concerns, whereas ethanol offers a greener alternative with slightly lower selectivity.

3.2 Supercritical CO₂ Extraction

Supercritical carbon dioxide extraction is increasingly preferred because it avoids solvent residues and preserves thermolabile compounds.

Rosemary wax extracted by supercritical CO₂ has shown strong hydrophobic activity when applied to cotton fabrics, producing contact angles near 122°.

Advantages include:

- solvent-free product,
- selective fractionation,
- lower oxidation risk,
- industrial reproducibility.

3.3 Hydrothermal and Green Extraction Routes

Emerging extraction technologies include:

- ultrasound-assisted extraction,
- microwave-assisted extraction,
- subcritical water extraction.

These methods reduce solvent consumption and shorten extraction time.

4. Formulation of Water-Repellent Treatment

After extraction, hydrophobic compounds require formulation into stable dispersions.

4.1 Emulsion Preparation

Typical formulation includes:

- plant wax extract,
- biodegradable emulsifier,
- natural binder (chitosan, starch, cellulose derivative),
- water phase.

Chitosan is particularly effective because it improves adhesion to cellulose fibers while maintaining biodegradability.

4.2 Surface Energy Modification

To improve repellency, fatty acids may be added:

- stearic acid,
- palmitic acid,
- oleic acid.

These compounds orient hydrophobic alkyl chains outward from the substrate surface.

4.3 Nanostructure Enhancement

Hydrophobicity improves significantly when nanoscale roughness is introduced.

Natural systems often combine plant extracts with:

- silica nanoparticles,
- TiO₂ nanoparticles,
- nanocellulose carriers.

This creates dual-scale roughness similar to lotus-leaf morphology.

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