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Green Extractions of Antimicrobial Biomaterials from Maple and Birch Leaves for Sustainable Textile Solutions

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Abstract

This study investigates a sustainable, zero-waste method for extracting antimicrobial biomaterials from Finnish maple (Acer platanoides) and birch (Betula pendula) leaves harvested in the fall, with potential applications in the textile industry. Three extraction methods were employed: subcritical acidified water extraction (40 bar), autoclave extraction (10 bar), and hot solvent extraction (1 bar), using varying temperatures (60°C–180°C) and solvents (70% ethanol and 15% acetic acid). The resulting extracts were tested for antimicrobial efficacy against Staphylococcus aureus microbes. Maple leaf extracts exhibited the largest inhibition zones (10–14 mm), especially when processed under acidified water with low pressures and temperatures, suggesting a high concentration of active antimicrobial compounds. This activity was linked to the phenolic compounds, including rutin, gallic acid, quercetin,tannic acid, and carboxylic acids, identified through FT-IR analysis. In contrast, birch leaf extracts demonstrated much lower antimicrobial activity, corresponding to a lower concentration of phenolic compounds and a less intense phenolic profile compared to maple leaves, which explains their reduced effectiveness. The extraction process follows a zero-waste model, where the feedstock is biomass from agricultural waste and the solid residual from the extraction can be converted into biofuel pellets, supporting a circular bioeconomy. The antimicrobial fractions derived from maple leaves offer a natural alternative for textile applications, serving both as antibacterial agents and natural colorants, reducing the need for synthetic chemicals. The use of abundant biomass ensures a scalable and sustainable solution that can be applied beyond Finland, contributing to global sustainability goals. The high-performance, eco-friendly textile solution offered by maple leaf extracts encourages the shift to circular, bio-based economies and supports industry sustainability.

Keywords: biomass, biomaterial, extraction process, antimicrobial agents, textile application, zero waste model, biofuel pellets, bio-based economy