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An ecofriendly route to enhance the antibacterial and textural properties of cotton fabrics using herbal nanoparticles from *Azadirachta indica* (neem)

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ABSTRACT

Application of nanoparticles in textile industry has recently risen owing to the possibility of incorporating desirable properties such as fascinating colors, enhanced stability, antibacterial activity and UV protection to the coated fabrics. In this study, natural herbal nanoparticles of different sizes were prepared from shade dried *Azadirachta indica* plant leaves using ball milling technique without additives. The obtained nanoparticles with different sizes were fully characterized using X-ray diffraction, Fourier transform infrared spectroscopy, UV–visible spectrophotometry, Dynamic light scattering, Scanning electron microscopy, X-ray fluorescence spectrometry and antimicrobial investigations. Herbal nanoparticles-chitosan nanocomposites were prepared and coated on cotton fabrics employing pad-dry cure method. The evaluation of antibacterial activity and UV-protection properties of the prepared herbal nanoparticles and their composites were obtained using antimicrobial and UV-visible analysis. Size, shape and morphological characteristics of herbal nanocomposites coated on fabrics were analyzed and correlated with un-coated fabrics. The antimicrobial properties of nanoparticles and their composites coated on cotton fabrics were analyzed against bacterial pathogens namely *Staphylococcus aureus* and *Escherichia coli*. UV-resistance and washing durability of the coated fabrics were also established. In addition, physical properties of the coated fabrics such as air permeability, crease recovery, tensile strength, tearing strength, thickness, bursting strength and GSM were also investigated. Understanding the functional properties of herbal nanoparticles coated on fabrics highlights their potential applications in protective clothing with enhanced antimicrobial and UV-protection properties.

1. Introduction

Nanotechnology plays an important role in textile industries such as dying, thermal stability, and chemical exposure [1,2]. In addition, fabrics with a broad spectrum of bacterial resistant properties provide the necessary protection from different pathogenic microorganisms. *Staphylococcus aureus* (*S. aureus*) and *Escherichia coli* (*E. coli*) are capable of causing various infections on the skin and other organs [3]. Testing of nanomaterials coated fabrics against such pathogens helps to develop functional fabrics with antibacterial activity for various applications.

Many of the herbal plants are traditionally used in natural medicine and exhibit antimicrobial activities. Natural herbal materials are ecofriendly, non-toxic and usually non-allergic to the general population, but have considerable issues such as short durability and low stability under ambient conditions [4]. Synthetic drugs used for antimicrobial treatments are expensive and have unpleasant side effects. Such problems are rectified by using herbal

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nanoparticles and introduce desirable functionality to fabrics [4,5]. The persistent exposure of UV radiation can cause serious problems for both living organisms such as premature aging of the skin, repression of the immune system, damage to the eyes and skin cancer and degradation of materials [6,7]. Fabrics coated with herbal nanomaterials are able to solve such problems with absorption of UV-radiation and antimicrobial properties. Many organic (alkaloids, flavonoids and phenolic) compounds commonly seen in plants show outstanding UV-absorption, antioxidant and photo protective properties [8]. Therefore, use of herbal nanoparticles for their antimicrobial and UV-protective property is a value added technology in textile industries.

Recently, many biopolymers have been used in textile, biomedical and pharmaceutical industries, owing to their easy accessibility and low toxicity [9-11]. Chitosan, an antimicrobial agent derived from natural chitin is an effective biodegradable polymer for applications in textile, agriculture, food science, pharmaceutical, chemical, cosmetics and food processing industries [12-14].

The extracts of medicinal plants like *Azadirachta indica* (*A. indica*) are tested for the functional finishing of textile materials [4,9,15]. *Azadirachta indica* commonly known as Neem, belongs to *Meliaceae* family commonly seen in South Asia, is established as a traditional antibiotic for a broad spectrum bacterial pathogens. Neem leaf extracts contain organic compounds such as nimbidin, nimbolide, mahmoodin, margolone, margolonone, and isomargolonon, all of which show good antibiotic properties [16].

So far, very few reports exist on exploring the application of nanoparticles derived from medicinal plants. In the present study, the *Azadirachta indica* nanoparticles (AINps) are obtained by ball milling of the plant leaves shade dried at room temperature. The functional properties of the AINps coated fabrics such as UV-protection, antimicrobial activity, washing durability and crease recovery are explored with a view to understand their possible applications in biomedical industries.

2. Materials and methods

2.1. Sample collection

Clean and fresh *A. indica* plant leaves (Fig. 1a) were collected from Tiruchengode area, Tamil Nadu, India. The collected plant leaves were washed with tap water followed by double distilled water and then shade dried at room temperature for 15 days. Care was taken to achieve uniform drying of all plant leaves.

2.2. Synthesis of herbal nanoparticles

Shade dried leaves (20 g) were ground to get coarse grained powders employing domestic mixer grinder. The obtained coarse *A. indica* leaf powders were (Fig. 1b) further ground using a ball mill (PM100; Retsch, Germany) by keeping the processing parameters such as diameter of ball as 10 mm, 300 rpm speed and a milling time of 15 h [17,18]. The obtained *A. indica* nanoparticles are labeled as AINp1. In order to check the reproducibility of our method, the milling was repeated for two more times by keeping the same process parameters using fresh batches of coarse powders. The obtained nanoparticles from the two repeated trials are termed as AINp2 and AINp3, characterized fully and were used for coating on fabrics followed by the evaluation of their functional properties.

2.3. Characterization

The XRD pattern of all prepared *A. indica* nanoparticles were obtained using Philips X'pert MPD powder diffractometer (X'Pert PRO, PANalytical, The Netherlands) operated with a long fine focus of Cu anode at 40 KV and 30 mA in Bragg-Brentano geometry. The XRD pattern was obtained in the 2θ range from 10° to 80° in a step-scan mode with a step size of 0.02°. The Fourier Transform Infrared Spectrophotometer (Spectrum 100; PerkinElmer, USA) was used in the range of 4000–400 cm^{-1} to record the FTIR spectra of all prepared nanoparticles using KBr as matrix. The constituents of elements in the prepared herbal nanoparticles were identified using X-ray fluorescence spectrometer (EDX-720; Shimadzu, Japan). The UV-visible spectra of the prepared nanoparticles were recorded employing UV-visible spectrophotometer (Cary 8454, Agilent, Singapore) operating in the UV to near IR (180–800 nm) spectral region. The sample for analysis was prepared by diluting 0.1 mL of sample in a cUVette to 2 mL using deionised water. The same procedure was employed to record the spectra for all samples. The particle size distribution was determined using a dynamic light scattering (DLS) technique with a sub-micrometer particle size analyzer (Nanophox, Sympatec, Germany). The particle size of all samples was measured in the range of 1–1000 nm at a scattering angle of 90°. All the prepared herbal nanoparticles were analyzed using a scanning electron microscope coupled with energy-dispersive X-ray analysis (JSM 6360; JEOL, Japan) to identify the morphology, microstructure, and elemental composition of the

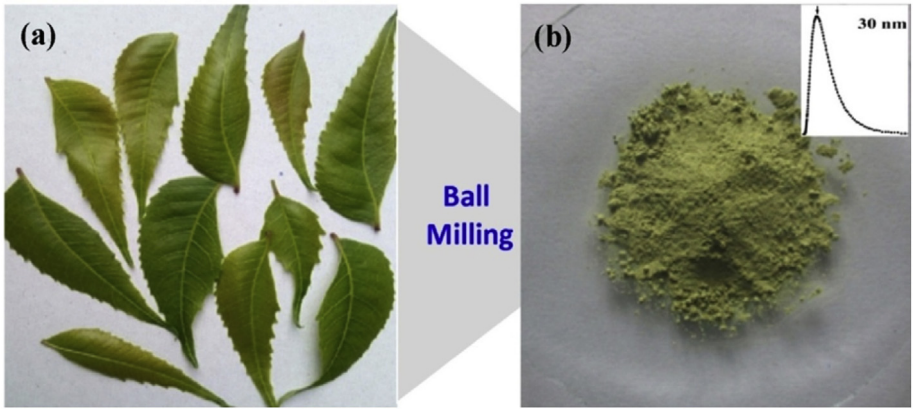

Fig. 1. Images of *A. indica* leaves and its nanoparticles.