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Gold nanoparticles mediated coloring of fabrics and leather for antibacterial activity

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ABSTRACT

Metal gold nanoparticles (AuNPs) were synthesized *in situ* onto leather, silk and cotton fabrics by three different modules, including green, chemical, and a composite of green and chemical synthesis. Green synthesis was employed using *Ginkgo biloba* Linn leaf powder extract and $HAuCl_4$ with the fabrics, and chemical synthesis was done with KBH_4 and $HAuCl_4$. For composite synthesis, *G. biloba* extract and KBH_4 were used to color and embed AuNPs in the fabrics. The colored fabrics were tested for color coordination and fastness properties. To validate the green synthesis of AuNPs, various instrumental techniques were used including UV–Vis spectrophotometry, HR-TEM, FTIR, and XRD. The chemical and composite methods reduce Au^{+} onto leather, silk and cotton fabrics upon heating, and alkaline conditions are required for bonding to fibers; these conditions are not used in the green synthesis protocol. FE-SEM image revealed the binding nature of the AuNPs to the fabrics. The AuNPs that were synthesized *in situ* on the fabrics were tested against a skin pathogen, *Brevibacterium linens* using LIVE/DEAD BacLight Bacterial Viability testing. This study represents an initial route for coloring and biofunctionalization of various fabrics with green technologies, and, accordingly, should open new avenues for innovation in the textile and garment sectors.

1. Introduction

In recent years, research has made it possible for textile and garment sectors to multi-functionalize various fabrics, including the development of fabrics with antibacterial [1,2], self-cleaning [2], and ultra violet protection [3–8] capabilities, representing innovation in the industry. Cotton fibers are typically spun into yarn or thread and used to make a soft, breathable textile, and the use of cotton dates to prehistoric times [9]. Leather is a durable and flexible material created by tanning animal rawhide and skin, often cattle hide, and can be produced at manufacturing scales ranging from cottage to heavy industry [10]. Silk as a natural protein fiber is widely used in the textile industry due to its inherently elegant sheen, excellent flexibility, environmental friendliness and comfort [3]. A great deal of previous research has been conducted on the coloring of silk and bamboo fabrics with noble metal nanoparticles [3,4,7,11,12] to enhance the functionality of the fabrics. Developing color on cotton, silk and leather is essential for the textile industry to attract the market with innovative fabrication like antibacterial, UV protection and so on. However, several dyes are not stable under washing and irradiation of sunlight and lead to color fade. Washing and light fading of dyes is a common phenomenon in textile research. The anisotropic AuNPs are different from traditional dyes, in that it is not the chromophore of traditional dyes but the shape and size of nanoparticles that determine the colors.

However, various methods of coloring by noble metals, including green, chemical, and a composite of green and chemical *in situ* synthesis of nanoparticles, are studied for the first time in the present study. For green synthesis, *Ginkgo biloba* Linn leaf powder extract was used as a metal reducing agent. The extract comes from a species of the Ginkgoaceae tree, which is the world's oldest tree, and is known primarily as a living fossil and the only surviving member of a certain group of seed plants. It grows naturally in very limited localities in the central Himalayan Mountains (Fig. 1). The leaves of this species are used extensively as a source of herbal remedy in medicinal phytochemicals [13].

2. Experimental

2.1. Chemicals and Materials

Commercial chemicals $HAuCl_4 2H_2O$ (>99%) and KBH_4 were purchased from Sigma-Aldrich, St. Louis, MO, USA. All chemicals were

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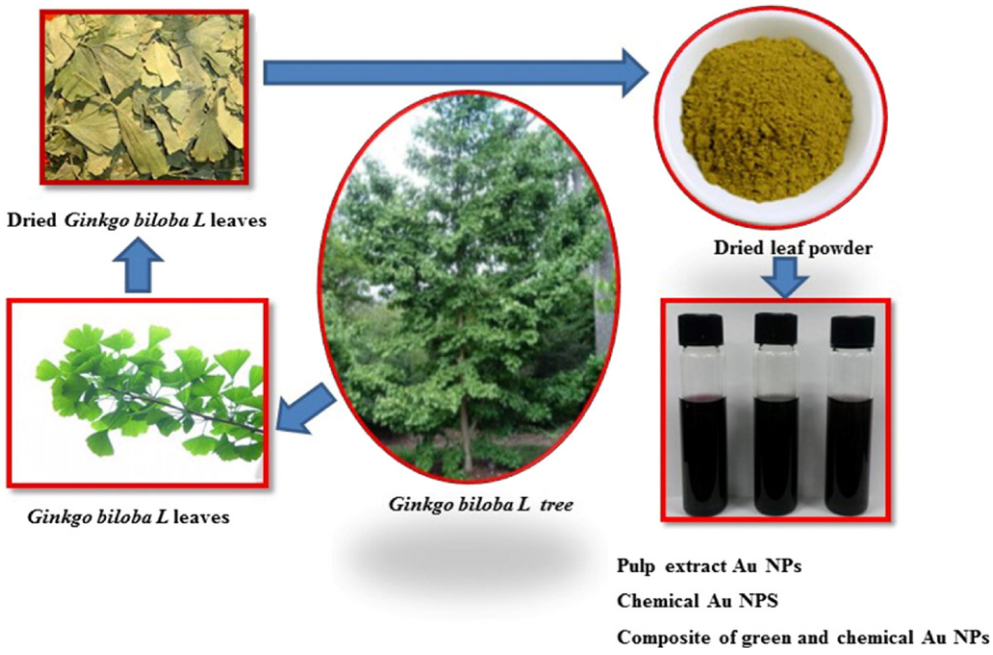

Fig. 1. *Gingko biloba* tree and colloidal AuNPs synthesized with different methods.

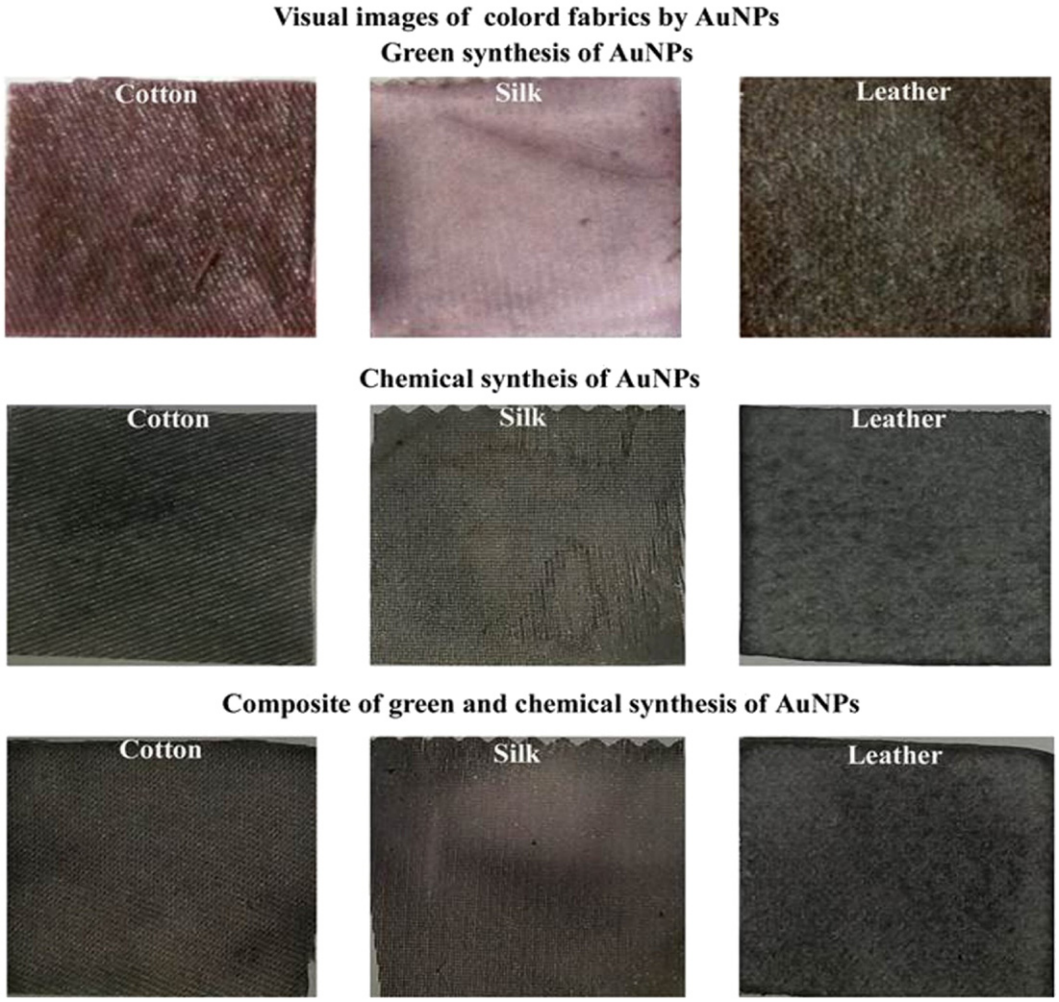

Fig. 2. Visual image of cotton, silk and leather fabrics dyed with different treatment methods.