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ORIGINAL ARTICLE

Phyto-crystallization of silver and gold by *Erigeron annuus* (L.) Pers flower extract and catalytic potential of synthesized and commercial nano silver immobilized on sodium alginate hydrogel

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Abstract A green, eco-friendly approach for the synthesis of silver and gold nanoparticles (AgNPs and AuNPs) using *Erigeron annuus* (L.) pers flower extract as both the reducing and capping agent is reported for the first time. Optimal nanoparticle production was achieved by adjusting various parameters including pH, extract concentration, metal ion concentration, and time. Initial verification of AgNP and AuNP production was done by visual observation and measuring surface plasmon spectra at 434 and 537 nm, respectively. The synthesized AgNPs and AuNPs were characterized by high resolution-transmission electron microscopy (HR-TEM), X-ray diffraction (XRD), energy dispersive spectrophotometry (EDS), Fourier transform infrared spectroscopy (FTIR) and zeta potential. The catalytic potential of *E. annuus* flower extract, silver ions, synthesized AgNPs, commercial grade AgNPs, and a mixture of flower extract and AgNPs immobilized on sodium alginate hydrogel beads (Na/Al HB) was analyzed. The ability of these immobilized materials to degrade methylene blue was investigated. Commercial grade AgNPs immobilized with Na/Al HB 1.5 g/20 mL were observed to have good catalytic activity followed by a mixture of syn-

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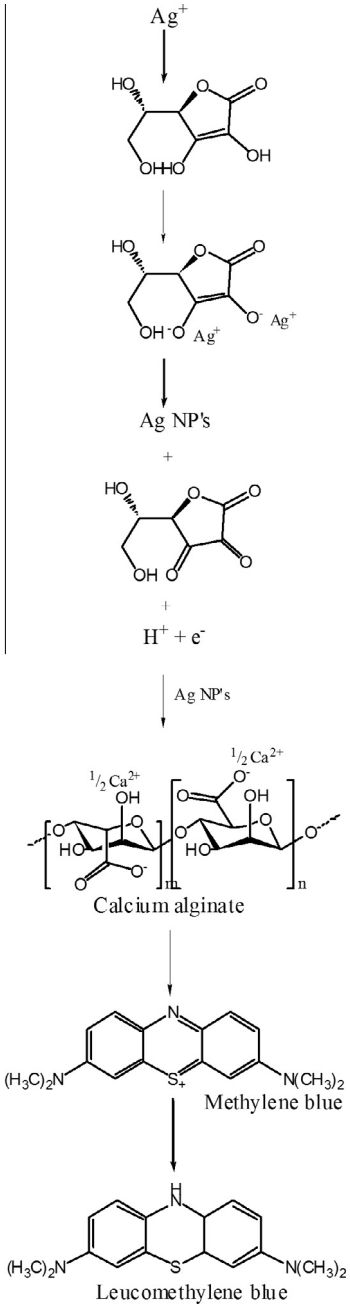
thesized AgNPs immobilized with Na/Al HB and *E. annuus* flower extract immobilized with Na/Al HB at 1.5 g/20 mL.

1. Introduction

Green nanotechnology is gaining more attention due to its eco-friendly and economical approach to nanoparticle synthesis. In recent years, researchers have been attracted by metal nanoparticles due to their unique optical, electrical, and biological properties, which make them central to numerous applications such as in catalysis, bio-sensing, imaging, drug delivery, and optical spectroscopy including surface-enhanced Raman scattering (SERS) [1]. Several chemical, electrochemical, photochemical, photophysical, and physical methods are employed for the synthesis and stabilization of different metal nanoparticles. However, these methods have been found to show certain toxicological effects in the medical research field [2]; also, some reagents are both hazardous and expensive. To overcome these limitations, we fabricated AgNPs and AuNPs in an eco-friendly and safe process by an easily obtainable flower extract. Several earlier studies reported that a safer mode of metal nanoparticle synthesis has been achieved by different microbes and by their biomolecules [3,4]. Recently, AgNP and AuNP synthesis using several flowers extracts as reducing and capping agents has been reported including *Mirabilis jalapa* [5], *Nyctanthes arbortristis* [6], *Ixora coccinea* [7], *Achillea wilhelmsii* [8], *Calotropis Procera* [9], *Carthamus tinctorius* [10], *Gnidia glauca* [11], *Lonicera japonica* [12], *Cassia Auriculata* [13], *Ipomoea indica* [14], and *Saraca indica* [15]. Among the various metal nanoparticles, silver nanoparticles have the greatest potential for applications in various industries and have unique catalytic, optical, and electrical properties [16].

In this manuscript, we report for the first time the synthesis of silver and gold nanoparticles by the reduction of metal silver and gold ions using *E. annuus* flower extract. The genus *E. annuus* belonging to the family Asteraceae (tribe Astereae), and involving about 150 species occurs in the northern hemisphere, mainly in North America. *E. Annuus* is an annual plant and reaches a height of up to 150 cm. It possesses erect, branched stems that end with inflorescences. The central disk florets are numerous, very small, and yellow; they are surrounded by 50–120 white ray florets. Both kinds of florets can be self-fertile. They often settle in places like roadsides and wastelands. *E. annuus* has been used in Chinese folk medicine for the treatment of indigestion, enteritis, epidemic hepatitis and hematuria. Constituents of the aerial part of *E. annuus* include γ-pyranone derivatives, flavonoids, phenolic acids and their derivatives, sesquiterpenoids, and cyclopentenone derivatives [17].

The main focus of this study is to reduce ionic silver and gold to gold and silver nanoparticles, respectively, using eco-friendly, non-toxic, cost effective and easily available biomaterial *E. annuus* flower extract. We investigated the effects of reaction parameters, such as pH, metal ion concentration, time of reaction and percentage of extract on the formation of silver and gold nanoparticles. We also studied the reduction of methylene blue dye catalyzed by (i) immobilization of *E. annuus* flower extract with synthesized AgNPs, (ii) *E. annuus* flower extract, (iii) silver ions, (iv) commercial AgNPs, and (v) control alginate beads (Scheme 1). Methylene blue is a thiazine dye used in many industrial applications like aqua culture,



Scheme 1 Possible mechanism of Ag NP formation and dye removal [15,23].