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ORIGINAL ARTICLE

Green synthesis of silver nanoparticles from marigold flower and its synergistic antimicrobial potential

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Abstract In the present study, silver nanoparticles were synthesized using flower broth of *Tagetes erecta* as reductant by a simple and eco-friendly route. The aqueous silver ions when exposed to flower broth were reduced and resulted in green synthesis of silver nanoparticles. The silver nanoparticles were characterized by UV–visible spectroscopy, zeta potential, Fourier transform infra-red spectroscopy (FTIR), X-ray diffraction, Transmission electron microscopy (TEM) analysis, Energy dispersive X-ray analysis (EDX) and selected area electron diffraction (SAED) pattern. UV–visible spectrum of synthesized silver nanoparticles showed maximum peak at 430 nm. TEM analysis revealed that the particles were spherical, hexagonal and irregular in shape and size ranging from 10 to 90 nm and Energy dispersive X-ray (EDX) spectrum confirmed the presence of silver metal. Synergistic antimicrobial potential of silver nanoparticles was evaluated with various commercial antibiotics against Gram positive (*Staphylococcus aureus* and *Bacillus cereus*), Gram negative (*Escherichia coli* and *Pseudomonas aeruginosa*) bacteria and fungi (*Candida glabrata*, *Candida albicans*, *Cryptococcae neoformans*). The antifungal activity of AgNPs with antibiotics was better than antibiotics alone against the tested fungal strains and Gram negative bacteria, thus significance of the present study is in production of biomedical products.

1. Introduction

The field of nanotechnology is one of the most active areas of research in current material science. The synthesis and characterization of noble metal nanoparticles such as silver, gold and platinum is an emerging field of research due to their important applications in the fields of biotechnology, bioengineering, textile engineering, water treatment, metal-based consumer products and other areas, electronic, magnetic, optoelectron-

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ics, and information storage (Rafiuddin, 2013). It has been reported that since ancient times silver metal is known to have antimicrobial activities (Pal et al., 2007) and silver nanoparticles (AgNPs) are of particular interest due to their peculiar properties and wide applications. Silver nanoparticles are used to treat infections in open wounds, chronic ulcers (Parashar et al., 2009) and in textiles, home water purification systems, medical devices, cosmetics, electronics, and household appliances (Wijnhoven et al., 2009), catalysis, biosensing, imaging, drug delivery, nanodevice fabrication and in medicine (Lee and El-Sayed, 2006; Nair and Laurencin, 2007; Jain et al., 2008), treatment of brucellosis (Alizadeh et al., 2013), anti-inflammatory (Wong et al., 2009), mosquito larvicidal (Rawani et al., 2013), etc.

Recently, resistance to commercially available antimicrobial agents by pathogenic bacteria and fungi is increasing at an alarming rate and has become a global threat. Drug resistance is one of the most serious and widespread problems in all developing countries (Stevanovic et al., 2012). Day by day treating bacterial infection is increasingly complicated because of the ability of the pathogens to develop resistance to available antimicrobial agents and existing antibiotics. Resistant pathogens may spread and become broader infection control problems within hospitals and communities as well. Resistant bacteria like *Staphylococci*, *Enterococci*, *Klebsiella pneumoniae* and *Pseudomonas* spp. are becoming more and more common (Tenover, 2006). To circumvent this, novel methods or novel strategies are required. The successful approach was the use of natural antimicrobials, combination or synergistic therapy and more recently use of metal nanoparticles.

Numerous methodologies are invented to synthesize noble metal nanoparticles of particular shape and size depending on specific requirements, because properties of metallic nanoparticles dependent on size and shape are of interest for applications ranging from catalysts and sensing to optics, antibacterial activity and data storage (Li et al., 2010). The surface to volume ratio of nanoparticles is inversely proportional to their size. The biological effectiveness of nanoparticles can increase proportionately with an increase in the specific surface area due to the increase in their surface energy and catalytic reactivity. Many methods have been used for the synthesis of silver nanoparticles, like chemical and photochemical reduction (Chen et al., 2001; Frattini et al., 2005) electrochemical techniques (Khaydarov et al., 2009) and radiolysis methods (Henglein, 1993).

However, in most of the methods hazardous chemicals and low material conversions and high energy requirements are used for the preparation of nanoparticles (Sathyavathi et al., 2010; Bar et al., 2009; Venkatesham et al., 2014). So, there is a need to develop high-yield, low cost, non-toxic and environmentally friendly procedures. In such a situation, biological approach appears to be very appropriate. Natural material like plants, bacteria, fungi, yeast, are used for synthesis of silver nanoparticles (Rangnekar et al., 2007; Ahmad et al., 2013; Sumana et al., 2013; Kotakadi et al., 2014; Vidhu and Philip, 2014).

Tagetes erecta (Marigold) is an ornamental plant belonging to the family Asteraceae. Flowers of this plant are used in garlands for social and religious purposes in most of the countries. It is native to Mexico and widely distributed in South East Asia including Bangladesh and India. The flowers are bright yellow, brownish-yellow or orange. Different parts of this plant including flower is used in folk medicine. In has been used for skin complaints, wounds and burns, conjunctivitis and poor eyesight, menstrual irregularities, varicose veins, hemorrhoids, duodenal ulcers, etc (Wichtl, 1994; Krishnamurthy et al., 2012). The flowers are especially employed to cure eye diseases, colds, conjunctivitis, coughs, ulcer, bleeding piles and to purify blood (Kirtikar and Basu, 1994; Manjunath, 1969; Ghani, 2003). Repellent and biocide activities of essential oils of *T. erecta* against mosquito species have been reported (Singer, 1987; Wells et al., 1992). Antimicrobial activity of gold nanoparticles of flower extract is reported by Krishnamurthy et al. (2012).

In the present work, an attempt has been made to synthesize silver nanoparticles using aqueous flower extract of *T. erecta* (Fig. 1A). The characterization was done using several spectral analyses. The synthesized silver nanoparticles were evaluated for their synergistic antimicrobial activity.

2. Materials and method

2.1. Chemicals

Fresh flowers of *T. erecta* were purchased from the local market of Rajkot Gujarat, India. All the chemicals were obtained from Hi Media Laboratories and Sisco Research Laboratories Pvt. Limited, Mumbai, India. Ultra purified water was used for experiment.

2.2. Preparation of the extract for synthesis of silver nanoparticles

Fresh flowers were thoroughly washed with tap water, followed by double distilled water and cut into small pieces. 5 g of cut flowers was boiled for 10 min in 100 ml ultra pure water and filtered through Whatmann No. 1 filter paper. The filtered *T. erecta* extract was used for the synthesis of silver nanoparticles.

2.3. Preparation of crude extract

The dried powder of the marigold flower was extracted by cold percolation method. The powder was first defatted with hex-

Figure 1A *Tagetes erecta* plant.