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Photocatalytic and antibacterial activities of gold and silver nanoparticles synthesized using biomass of *Parkia roxburghii* leaf

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ABSTRACT

The present study reports a green approach for synthesis of gold (Au) and silver (Ag) nanoparticles (NPs) using dried biomass of *Parkia roxburghii* leaf. The biomass of the leaf acts as both reductant as well as stabilizer. The as-synthesized nanoparticles were characterized by time-dependent UV–visible, Fourier transform infrared (FT-IR), powder X-ray diffraction (XRD), and transmission electron microscopy (TEM) analyses. The UV–visible spectra of synthesized Au and Ag NPs showed surface plasmon resonance (SPR) at 555 and 440 nm after 12 h. Powder XRD studies revealed formation of face-centered cubic structure for both Au and Ag NPs with average crystallite size of 8.4 and 14.74 nm, respectively. The TEM image showed the Au NPs to be monodispersed, spherical in shape with sizes in the range of 5–25 nm. On the other hand, Ag NPs were polydispersed, quasi-spherical in shape with sizes in the range of 5–25 nm. Investigation of photocatalytic activities of Au and Ag NPs under solar light illumination reveals that both these particles have pronounced effect on degradation of dyes viz., methylene blue (MB) and rhodamine b (RhB). Antibacterial activity of the synthesized NPs was studied on Gram positive bacteria *Staphylococcus aureus* and Gram negative bacteria *Escherichia coli*. Both Au and Ag NPs showed slightly higher activity on *S. aureus* than on *E. coli*.

1. Introduction

Over the past two decades noble metal nanomaterials have gained much popularity due to their several technological and medical applications such as in molecular imaging [1], drug delivery [2], and development of materials and medical devices for diagnosis and treatment [3,4]. Au NPs have promising bio-medical uses particularly as scaffold for drug and gene delivery. New drug delivery strategies can be made with Au NPs utilizing their inherent low toxicity, high surface to volume ratio and tunable stability. Moreover, functionalized Au NPs are used as nanocarriers in pharmaceutical field for intracellular drug and gene delivery [5]. Similarly, Ag NPs are known to exhibit antifungal and anti-inflammatory activities and are effective as antibacterial agents against various pathogenic microbes [6–8]. Therapeutic uses of these NPs are safe, free from side effects and effective in a variety of diseases.

Various methods are employed to prepare Au and Ag NPs, the most important ones are chemical reduction, ultraviolet and microwave radiation, and photochemical and sonochemical methods [9–18]. Owing to associated hazards and toxicity of chemicals, it has become obligatory to look for an alternative eco-friendly, simple and reliable synthetic method which is based on the reducing capacity of some compounds from natural organisms. Therefore, exploration of biosynthesis of nanomaterials is currently receiving immense interest due to ever-growing significance of green chemistry practices. A good number of reports have appeared in the literature on green synthesis of Au and Ag NPs using biomaterials like bacteria, different plant parts, fungi, and algae [19–27].

A comprehensive literature survey reveals that there is no report on the biosynthesis of Au and Ag NPs using dried biomass of *Parkia roxburghii*, which is traditionally used as food source among local communities in northeast Indian states [28]. *P. roxburghii* is a less known legume from northeast India that belongs to the family of *leguminoseae* of sub-family *mimisoideae*. Seeds and tender pods of this legume are reported to cure stomach disorder and regulate liver function. Moreover, their pods pounded in water are used for cleaning face and head. As part of our current endeavor [29–32] on synthesis and application of nanomaterials, including those of noble metals, we wish to report herein, biosynthesis of Au and Ag NPs using dried biomass of *P. roxburghii* leaf. Also presented are studies on their photocatalytic activity on degradation of methylene blue (MB) and rhodamine B (RhB) as well as their antibacterial activity on *Staphylococcus aureus* and *Escherichia coli*. It is important to mention that with rapid growth of textile industries across the globe, use of organic non-biodegradable dyes is continuously increasing thus causing considerable rise in environmental pollution. Knowing that Au and Ag NPs obtained from phytochemicals do exhibit remarkable activity towards photocatalytic degradation of dyes [33,34] it is deemed appropriate to evaluate efficiency of as-synthesized Au and Ag NPs towards

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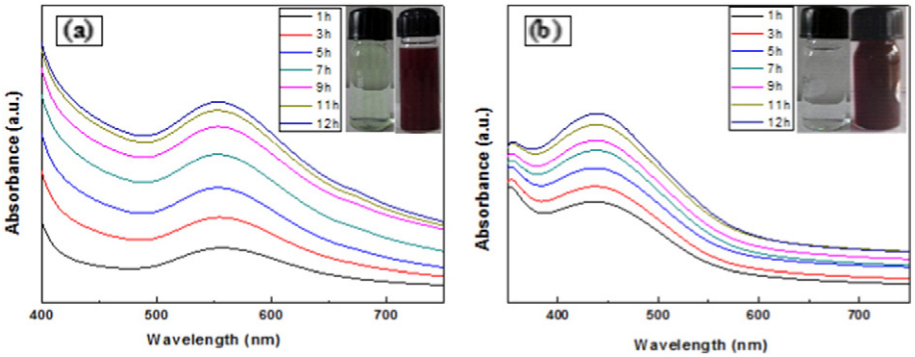

Fig. 1. (a) Time dependent UV–visible spectra of gold nanoparticles and (b) time-dependent UV–visible spectra of silver nanoparticles.

photocatalytic degradation of one or more of these potentially harmful dyes. It is known from literature that Au and Ag NPs cause irreparable damage to the cellular membrane, which enables accumulation of nanoparticles in the cytoplasm [35,36]. It was suggested that antimicrobial activity of these NPs arises due to this damage and therefore smaller size of NPs would be able to penetrate across cell membrane [37,38] more effectively.

2. Experimental

2.1. Materials and Physical Measurements

The leaves of *P. roxburghii* were brought to the laboratory, cleaned thoroughly by distilled water, and then shade dried for a week. The dried leaves were ground to powder in a glass mortar. Chloroauric acid ($HAuCl_4$), silver nitrate ($AgNO_3$), and sodium borohydride (SB) were purchased from Sigma-Aldrich. Methylene blue (MB) and rhodamine B (RhB) were obtained from Merck India Ltd. Absorption spectra were recorded on a Carry Varian-450 UV–visible spectrophotometer. XRD measurements were carried out on a Bruker AXS D8-Advance powder X-ray diffractometer with Cu-Kα radiation (λ = 1.5418 Å) with a scan speed of 2°/min. Transmission electron microscopy images were obtained on a JEOL, JEM2100 equipment. TEM grids were prepared using a few drops of the nanoparticles followed by drying. FT-IR spectra were recorded on KBr matrix with Bruker 3000 Hyperion Microscope with Vertex 80 FT-IR system.

2.2. Biosynthesis of Au NPs and Ag NPs

For the synthesis of Au NPs, approximately 1 g of dry leaf powder was mixed with 100 ml (10^{-3} M) aqueous solution of $HAuCl_4$ and stirred magnetically at room temperature for 12 h. The progress of the reaction was routinely monitored by observing color change as well as by recording UV–visible spectrum of small aliquot of mixture at regular interval. The initial light yellow solution turned to deep red, indicating formation of colloidal gold. The supernatant containing Au NPs was collected by centrifugation at 10,000 rpm. The solution was dried in a vacuum desiccator and the solid Au NPs were collected. The same procedure was followed for the Ag NPs where approximately 1 g of dry leaf powder was mixed with 100 ml (10^{-3} M) aqueous solution of $AgNO_3$ and stirred magnetically at room temperature for 12 h. The

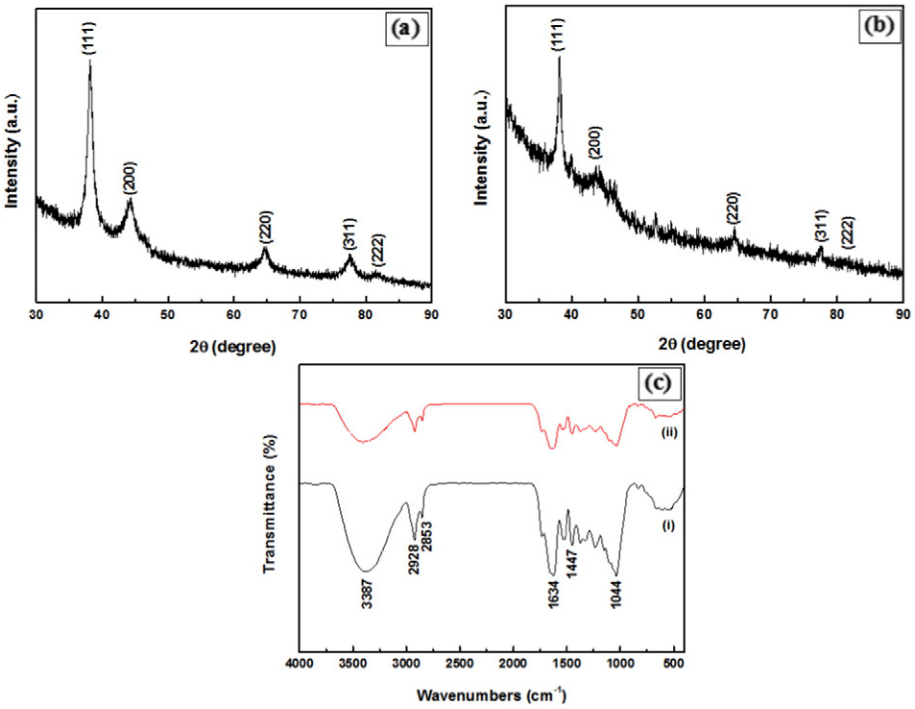

Fig. 2. (a) XRD pattern of gold nanoparticles, (b) XRD pattern of silver nanoparticles, and (c) FT-IR spectrum of (i) gold nanoparticles and (ii) silver nanoparticles.