



Utilization of market vegetable waste for silver nanoparticle synthesis and its antibacterial activity



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ABSTRACT

In the present study, silver nanoparticles (AgNPs) were synthesized using market vegetable waste extract. The formation of AgNPs was observed by a change in the reaction mixture colour from colourless to brown, after the addition of vegetable waste extract. The bioreduced AgNPs were characterized using transmission electron microscopy, scanning electron microscopy coupled with energy dispersive spectroscopy and other standard techniques. The antibacterial activity of the bioreduced AgNPs was analyzed for both Gram-negative (*Klebsiella* sp.) and Gram-positive bacteria (*Staphylococcus* sp.). The results showed that the bioreduced AgNPs effectively inhibited the growth of the tested bacterial strains. The study revealed the effective method of utilizing market green vegetable waste for the synthesis of AgNPs with high antibacterial efficiency.

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1. Introduction

In recent decades, synthesis of silver nanoparticles have blossomed due to their wide range of applicability in the fields of science and technology, and medicine such as catalysis, photocatalysis, chemical and biosensing, antibacterial, catheters, food containers and anticancer [1–7]. In the past decades, several physico-chemical methods have been developed for AgNPs synthesis [8]. Nevertheless, these physico-chemical methods are either costly or involving the use of potential hazardous chemicals that can harm the human and the eco-system [9]. In order to protect the environment from the hazardous chemical pollution, a biosynthesis is proposed as a simple, sustainable alternative, environment friendly and cost-effective method.

Plant extracts derived from various species are regarded as a highly desirable system for nanoparticle synthesis due to their tremendous capability to produce a wide range of phytochemicals with profound reducing potential. Several studies have reported the synthesis of AgNPs using plants [10–12]. However, utilization

of vegetable waste for the production of AgNPs has not been reported. Thus, the present study describes the green synthesis of AgNPs using vegetables waste.

2. Materials and methods

2.1. Vegetable waste collection

Vegetable waste was collected from a waste disposal yard of a vegetable market (Wednesday Market), Mallasamudram, Namakkal District, Tamil Nadu, India. The trading of vegetable in this city is approximately 2–5 tons/Wednesday. The 200–500 kg quantity of vegetable trading produces a huge amount of wastes in the form of discarded vegetables, fresh skins of vegetables, fresh/damaged leaves etc. The fresh vegetable waste was collected in plastic bags and brought to the laboratory. The vegetable waste was washed thoroughly with tap water and double distilled water until no impurity remained. The mixed vegetable waste (100 g) was separated and added to 500 mL of sterile double distilled water and crushed using mortar and pestle [13]. The extract was filtered through a Whatman No.1 filter paper and stored at 4 °C for further experiments.

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2.2. AgNPs synthesis

Ten millilitre of mixed vegetable waste extract was added to 90 mL of 1 mM AgNO₃ solution, and the resulting coloured mixture was incubated in a rotary shaking incubator (200 rpm) at 37 °C for 5 h. The bioreduction of silver was observed by a change in the reaction mixture colour from colourless to brown. The produced AgNPs were separated by centrifugation at 12,000 rpm for 15 min and the pellets were re-dispersed in sterile distilled water 2–3 times to remove residues. The purified pellets were dried and used for further characterization studies.

2.3. Characterization of AgNPs

The optical absorption spectra of the synthesized AgNPs were observed using UV-vis spectrophotometer (Elico-SL 164, Hyderabad, India). The elemental composition of the AgNPs was confirmed by scanning electron micrograph-energy dispersive spectroscopy (SEM-EDS; Jeol JSM 6390). The surface morphology and size of the AgNPs were measured using transmission electron microscopy (TEM, FEI Tecnai TF 20 high resolution). X-ray powder diffraction was used to determine the crystalline nature of the samples (XPERT-Pro diffractometer using Cu-K α radiation). Scanning was done in the region of 2 θ from 20 to 80° at 0.04°/min with a time interval of 2 s. Fourier transform infrared spectroscopy (FT-IR) spectra of AgNPs were obtained with a Perkin-Elmer FTIR spectrophotometer (IRAffinity-1S) in the diffuse reflectance mode at a resolution of 4 particles cm⁻¹ in KBr pellets.

2.4. Antibacterial activity

Strains of bacterial pathogens such as *Klebsiella* sp. (Accession Number: KC899845), and *Staphylococcus* sp. (Accession Number: KC688883) were maintained in nutrient agar. The antibacterial activity of the biologically synthesised AgNPs was determined according to Ravichandran et al. [14]. Silver nitrate was used as a control for the experiments. Three repetitions were carried out for the experiments.

3. Results and discussion

The vegetable waste extract was used in the reduction of AgNO₃ into AgNPs and the bioreduction was visually confirmed by the colour change in the reaction mixture from colourless to brown. The UV-Vis spectroscopy analysis of the AgNPs showed an absorbance

band at 400–500 nm. The results are consistent with previous studies that reported the surface plasmon resonance of AgNPs of 400–500 nm [10,13–15]. The phytochemicals present in the vegetable waste were responsible for the reduction of AgNO₃ into AgNPs. The size, shape and morphology of the synthesised AgNPs were investigated by TEM and presented in Fig. 1(a). The TEM results showed that the AgNPs were dispersed uniformly and having a spherical shape with the size range of 10–90 nm. The particle size distribution of the synthesised AgNPs is shown in Fig. 1(b). The uniform dispersion of AgNPs could be due to capping-and-stabilizing biomolecules and/or phytochemicals present in the vegetable waste extract. To further validate the formation of AgNPs, the samples were analyzed using SEM-EDS and the results are presented Fig. 2(a). The EDS spectrum showed strong silver signals at 3 keV. The results are in agreement with previous studies reported the strong peak for AgNPs at 3 keV [11,16]. The EDS quantitative analysis showed the presence of silver (100%) without any contaminants.

The crystalline nature of the synthesised AgNPs was confirmed using XRD analysis (Fig. 2 b). The strongest peak was observed at 33.36° which corresponds to the predominant growth of the crystal in the direction of (1 1 1) plane. The second strongest peak was identified at 48.26° which corresponds to the plane (2 0 0) of AgNPs. Two minor peaks reflections were observed at 55.3 and 77.6° assigned to the (1 4 2) and (3 1 1) planes of AgNPs, respectively. All the four characterization peaks for AgNPs reveal that the nanoparticles were crystalline nature. The results are in agreement with several studies reported that the crystalline nature of biologically synthesised AgNPs [17–19].

FTIR analysis was carried out to identify the possible biomolecules and/or phytochemicals responsible for the bioreduction, capping-and-enhanced stabilization of AgNPs synthesised from vegetable waste. The FTIR spectrum shows many peaks indicating the presence of different functional groups present in the AgNPs (Fig. 3). The peak at 3459 cm⁻¹ was assigned to N–H stretching vibration of amines. The small absorption peak at 2940 cm⁻¹ and strong absorption peaks at 1770, 1585, 1250, and 1051 cm⁻¹ could be ascribed as O–H, N–H and C–O stretching of alcohols, phenols and carboxylic anions. The plane peak at 632 cm⁻¹ indicates the presence of alkaloids. The results confirmed that the presence of phytochemicals and/or biomolecules in the vegetable extract could be responsible for the reduction. The mentioned peak positions have also observed in the sample of AgNPs synthesised by other plant extracts [20,21].

Antibacterial activity of AgNPs was evaluated and presented in Fig. 4. The results revealed that *Klebsiella* sp., and *Staphylococcus*

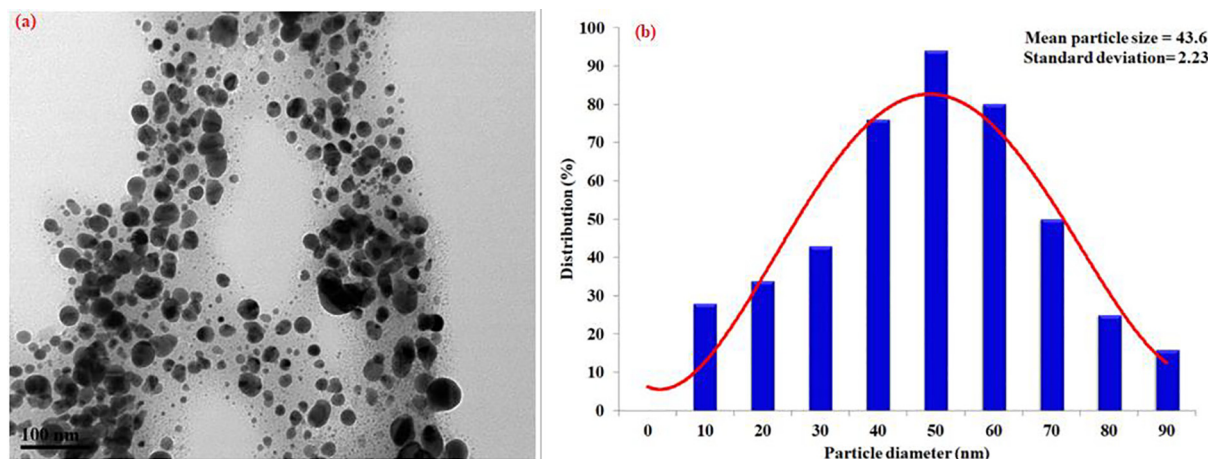


Fig. 1. (a) TEM image of AgNPs synthesized from vegetable waste extract, and (b) particle size distribution of synthesized AgNPs.

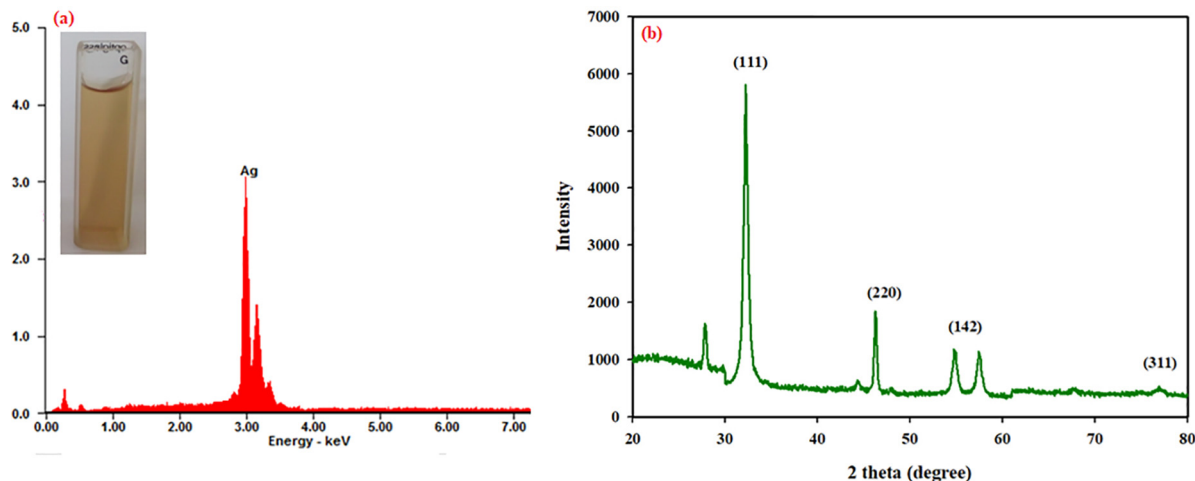


Fig. 2. (a) SEM-EDX spectrum of AgNPs and (b) XRD pattern of AgNPs.

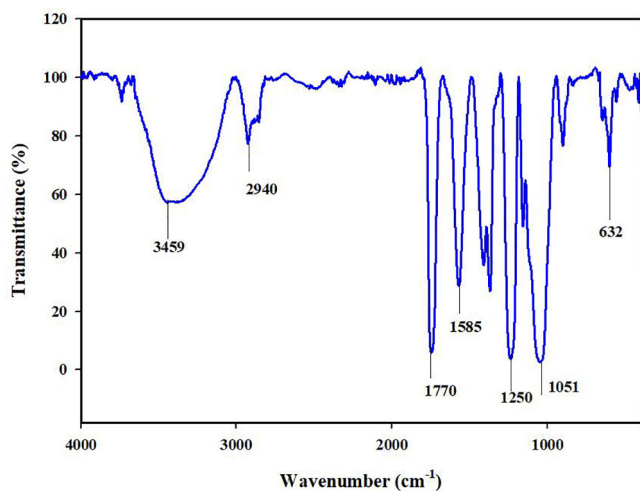


Fig. 3. FTIR spectrum of AgNPs obtained from vegetable waste extract.

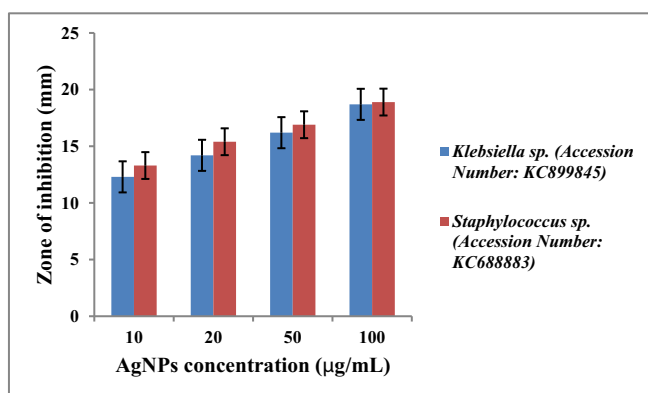


Fig. 4. Antibacterial activity of AgNPs (Error bars indicate standard deviation of means, where absent, bars fall within symbols) The 50 µg/mL concentration of AgNPs showed significant difference ($P < 0.01$) compared to the other concentrations (10, 20 and 100 µg/mL) of AgNPs.

sp., were highly susceptible to bioreduced AgNPs. The diameter of the inhibition zones was 18.7 mm for *Klebsiella* sp., and 19 mm for *Staphylococcus* sp., at 100 µg/mL. However, decreased zone of

inhibition was observed at 10, 20 and 50 µg/mL. 50 µg/mL of AgNPs showed a significant difference ($P < 0.01$) compared to the other concentrations (10, 20 and 100 µg/mL) of AgNPs. The results indicated that the antibacterial activity of the bioreduced AgNPs was directly proportional to the concentration of nanoparticles. The results are consistent with previous studies reporting the antibacterial activity of biologically synthesised nanoparticles against a wide range of bacterial pathogens [14,22].

4. Conclusion

A simple, economic and actual green route for the production of AgNPs using green vegetable waste was reported in this study. The vegetable waste extract played a significant role in the bioreduction of AgNO₃ into AgNPs. AgNPs demonstrated excellent bactericidal activity against clinical pathogens. The utilization of market green waste not only produces AgNPs also reduces the risk of pollution.

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