

Biosynthesis of silver nanoparticles using *pennyroyal* water extract as a green route

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Abstract Synthesis of silver nanoparticles (Ag NPs) using water extract of *pennyroyal* is carried out successfully at ambient temperature. The obtained Ag NPs were characterized, using different methods including ultraviolet–visible spectroscopy, powder X-ray diffraction, scanning electron microscopy and transmission electron microscopy (TEM). TEM study showed that mean diameter and standard deviation for the formation of silver nanoparticles were 19.14 ± 9.791 nm.

Keywords Biosynthesis · Silver nanoparticles · Pennyroyal · Green route

Introduction

Silver nanoparticles (Ag NPs) are the most applicable and interesting NPs between researchers. Nanomaterials have interested a lot of attentions due to the remarkable difference in structural and physical properties of atoms and molecules [1]. Nanomaterials can improve the human life and its environment. Several physical and chemical processes [2] for synthesis of metal nanoparticles have been investigated for real life such as medicine [3], catalysis [4] and detection of DNA hybridization [5]. Ag NPs can be synthesized using physical and chemical methods such as ultrasonic fields, UV irradiation and photochemical

reduction [5], but the use of toxic chemicals as reducing agents in many of these routes is potentially dangerous to the environment and biological systems [6]. Green routes for synthesis of Ag NPs nanoparticles by a biological process using plant extract containing phytochemical agents have attracted considerable interest in recent years. Such green process can lead the formation of nanoparticles to more biocompatible, environmental benign and cost-effective products [7]. On the basis of the available literature, we hypothesize that *pennyroyal* could be used in the synthesis of Ag NPs. The nanoparticles were characterized by UV–visible spectroscopy, XRD and TEM analysis.

Materials and methods

Preparing the water extract of *pennyroyal*

Green leaves of *pennyroyal* were collected in September 2014, from Sabalan region of Iran. AgNO_3 (99.80 %) was purchased from Merck. All aqueous solutions were prepared using double-distilled water. *Pennyroyal* green leaves were washed and dried in shade during a week. The dried leaves were then ground into powder and kept at 25 °C until further analyses. The ground of *pennyroyal* leaves (10 g) were extracted with double-distilled water (ratio 1:10 w/v), with boiling the mixture for 10 min in a water bath. The mixture was then filtered and centrifuged at 4000 rpm for 10 min to remove any proteins from the extract. The extract was then kept in a dark bottle at 25 °C until for 1 week.

Synthesis of silver nanoparticles

A solution containing 100 ml of AgNO_3 (0.01 M) and 20 mL of the water extract of *pennyroyal* was mixed at

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Fig. 1 UV–Vis absorption spectra of Ag/pennyroyal emulsion after 1 day

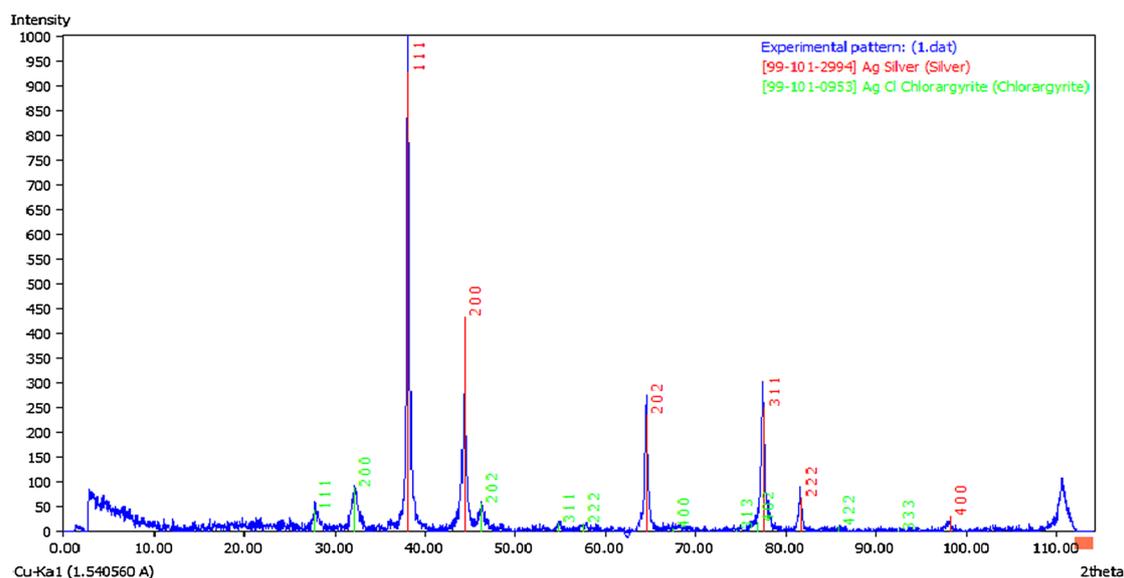
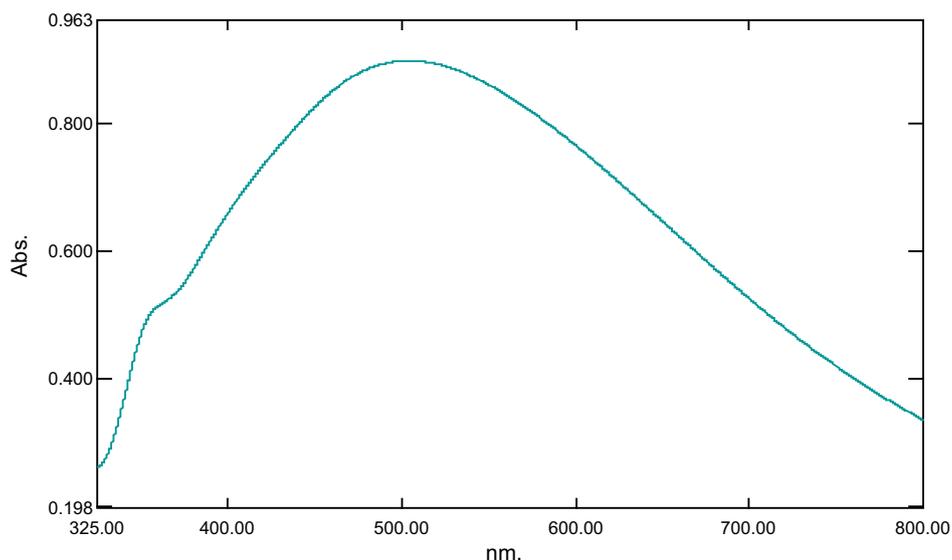


Fig. 2 XRD patterns of silver NPs synthesized by *pennyroyal* water extract

room temperature (25 °C) for 1 day with vigorous stirring. Silver nanoparticles were gradually obtained during the reaction. Then, the solution was filtered with membrane filter paper (0.2 μm) and was washed by double-distilled water to remove residues. Ag NPs were dried in an oven at 80 °C for 24 h and were collected in an inert atmosphere for further evaluations.

Characterization of silver nanoparticles

The morphology of the Ag NPs was studied using the X-ray diffraction (XRD, Inel, EQUINX 3000). The TEM observations were carried out using (TEM, Zeiss, EM 10 C-100 kV) electron microscope, and the SEM was

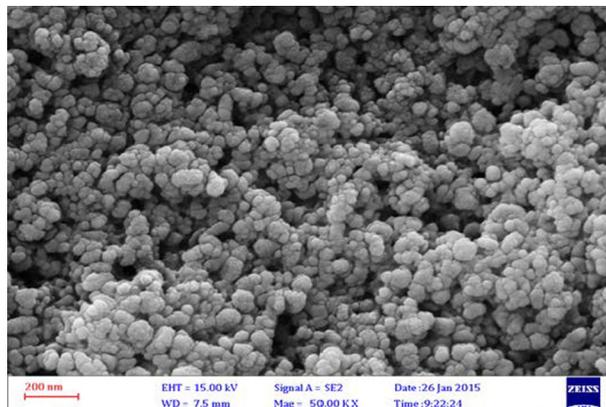


Fig. 3 SEM image of Ag/pennyroyal NPs



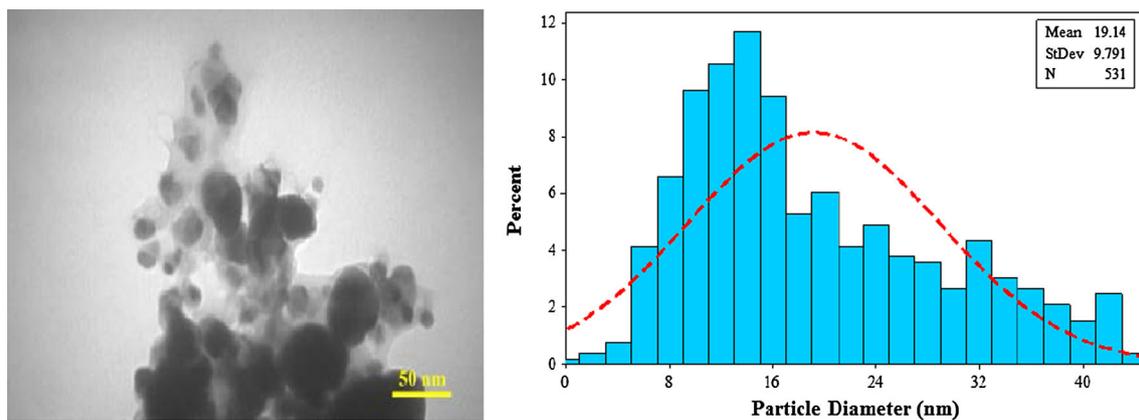


Fig. 4 TEM image and corresponding size of Ag/pennyroyal

performed using a Zeiss Σ IGMMA VP instrument to study the morphology of Ag NPs. The UV–visible spectra were recorded over the 200–800 nm rang with an UV Bio-TEK UV–visible spectrophotometer.

Results and discussions

The UV–Vis absorption spectra recorded for Ag NPs solution and suspension in water are shown in Fig. 1. The maximum absorption at 490 nm can be attributed to the plasma resonance absorption of silver particles.

The X-ray diffraction patterns recorded for silver nanoparticles are shown in Fig. 2. The X-ray patterns revealed diffraction peaks at 2θ of about 38.24, 44.42, 64.44, 77.44 and 81.25 which could be attributed to the 111, 200, 220, 311 and 222 orientations, respectively, which are matched to the face-centered cubic (fcc) phase of Ag $^{\circ}$.

SEM images of silver nanoparticles, synthesized by this method, are shown in Fig. 3. SEM images of silver nanoparticles confirm the existence of small and uniformly spherical nanoparticles. In Fig. 3, the uniform nanoparticles of Ag $^{\circ}$ can be seen, also the formation of nanoparticles and stabilization with pennyroyal water extract that is the major deal for prevention of agglomeration of Ag nanoparticles. The average particle size of Ag-NPs synthesized using pennyroyal water extract was about 19.14 ± 9.791 nm.

TEM image of Ag NPs and their size distribution are shown in Fig. 4. The result showed narrow particle size distributions. Moreover, the mean diameter and standard deviation of silver nanoparticles is 19.14 ± 9.791 nm.

Conclusions

It can be concluded that silver nanoparticles were synthesized with an average size of 19.14 ± 9.791 nm and spherical in shape, using the water extract of pennyroyal at

room temperature. Silver nanoparticles were characterized by UV–visible, SEM, TEM and XRD. The green synthesis of nanoparticles is an eco-friendly method because of the usage of natural products.

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