Hindawi Publishing Corporation
Journal of Nanomaterials
Volume 2016, Article ID 8026843, 8 pages
http://dx.doi.org/10.1155/2016/8026843

Research Article

Green Synthesis of Silver Nanoparticles by Using *Ziziphus nummularia* Leaves Aqueous Extract and Their Biological Activities

Farhat Ali Khan,[1,2] Muhammad Zahoor,[2] Abdul Jalal,[2] and Aziz Ur Rahman[2]

[1]*Department of Pharmacy, Sarhad University of Science and Technology, Peshawar, Pakistan*
[2]*Department of Chemistry, University of Malakand, Chakdara, Lower Dir, Khyber Pakhtunkhwa 18000, Pakistan*

Correspondence should be addressed to Muhammad Zahoor; mohammadzahoorus@yahoo.com

Received 24 March 2016; Revised 17 May 2016; Accepted 6 June 2016

Academic Editor: Xuping Sun

Silver nanoparticles of *Ziziphus nummularia* leaves extract were synthesized and were characterized by UV-Visible spectrophotometry, particle size analyzer, X-ray diffraction (XRD), differential scanning calorimetry (DSC), Fourier transform infrared spectroscopy (FT-IR), SEM, TGA, and EDX. The XRD pattern reveals the FCC structure of Ag nanoparticles. FTIR spectra confirmed the presence of Ag-O bonding. UV-Visible spectroscopy results confirmed the existence of Ag because of the particular peak in the region of 400–430. The SEM analysis confirmed spherical and uniform Ag nanoparticles with diameter ranging from 30 nm to 85 nm. The EDX analysis revealed strong signals in the silver region and confirmed the formation of silver nanoparticles. The antioxidant potential and antifungal and antimicrobial potential of the leaf extract and silver nanoparticles were also determined. The antioxidant property was determined using DPPH assay. The antibacterial, antifungal, and antioxidant properties were better for the silver nanoparticles than the aqueous leaf extract. The minimum inhibitory concentration (MIC), minimum bactericidal (MBC), and minimum fungicidal concentration (MFC) of plant extract and prepared silver nanoparticles were also tested. The hair growth properties of plant extracts and their respective nanoparticles were observed and good results were noted for nanoparticles as compared to the leaf extract.

1. Introduction

In recent years, efforts have been made by scientists to produce nanoparticles of specific nature and size. The role of nanoparticles has been immensely increased in various fields of drug delivery, catalysis, molecular imaging, DNA sequencing, biosensors and electrical device, and so forth [1–3]. Nanoparticles are very vital in all fields of modern sciences including biology, chemistry, physics, electronics, biotechnology, and medicine. A nanoparticle shows properties which are built on certain features such as shape, size, scattering, and morphology [4].

Recently various methods for the synthesis of silver nanoparticles like physical, photochemical, chemical, and biological methods have been reported by different authors. All methods have their own merits and demerits with general difficulties being scalability, particle size, costs, and size distribution. Various physical processes are used for the synthesis of nanoparticle like evaporation condensation, which is normally carried out by means of a tube heating system at distinctive pressure. Among them, the thermal breakdown technique was organized to manufacture silver nanoparticles in fine particles form [5]. Two types of approaches can be used in the photochemical synthesis, that is, the photophysical (up to bottom) and photochemical (bottom to up) ones. The nanoparticles are fashioned by the direct photoreduction of various metal sources or reduction of various metal ions by using photochemically generated excite species which is frequently called photosensitization in the synthesis of silver nanoparticles [6, 7]. In chemical synthesis the silver nanoparticles are formed by adding various main chemical components such as $AgNO_3$, a reducing agent like ethylene glycol, and capping agent (PVP) for the purpose of controlling the growth of nanoparticles and preventing it from

aggregating process. In contrast during biological synthesis of silver nanoparticles the molecules of reducing agent and the stabilizer are replaced and formed by source of living organisms like fungi, bacteria, yeast, and plants [8]. Silver nanoparticles are mostly used, as an antimicrobial agent in the medical field [9, 10] due to its strong bactericidal and inhibitory effects as well as a wide range of antimicrobial activity for fungi, bacteria, and virus as early period [11]. Silver nanoparticles are extensively used as an antibacterial agent in every sector of life such as industry, health, food storage, and textile coatings in a numeral ecological applications [12–16].

Owing to the importance of nanoparticles in various fields, the present study was aimed at synthesizing silver nanoparticles (Ag-NPs) through biological methods and characterized by various analytical techniques. The antimicrobial, antioxidant, and hair growth activities of the synthesized nanoparticles were also determined and compared with that of crude leaf extract.

2. Material and Methods

Silver nitrate was purchased from Scharlau Spain. Leaves of *Ziziphus nummularia* were collected from the Tehsil Dargai District Malakand of Khyber Pakhtunkhwa, Pakistan.

After collection the leaves were cleaned with distilled water and were crushed with motor and pestle. Then five grams of the crushed leaves was taken in conical flask and was soaked in 100 mL of distilled water. Then the soaked leaves were boiled for fifteen minutes with constant stirring and then filtered through a filter paper (Whatman paper number 1) to get the leaves extract and were stored in the refrigerator till further use. Throughout the whole experiment, doubly deionized water was used.

Silver nanoparticles were prepared via standard method devised by Evanoff Jr. and Chumanov [17]. 0.085 g of silver nitrate was dissolved in 100 mL of distilled water to get $AgNO_3$ solution (1 mM solution of silver nitrate). $AgNO_3$ solution was first stirred for one minute at room temperature and then *Ziziphus nummularia* leaves extract was added. Reaction mixture was kept on shaker for 4 hours. After the addition of leaves extract the color of the solution immediately changed from colorless to yellowish brown. This change in color indicated the formation of Ag-NPs. Different ratios (6 : 1, 8 : 1, 10 : 1, 12 : 1, and 14 : 1) of Ag solution were used against fixed ratio of leaves extract to get different shapes and sizes of Ag-NPs. UV-Vis spectrum of the prepared nanoparticles was measured on PerkinElmer spectrophotometer. The optimization is reached at ratio 12 : 1 which was confirmed from color of the solution and UV-Visible spectra.

Characterization of Ag-NPs was done using standard characterization techniques like UV-Visible (UV-Vis) spectroscopy, SEM, FTIR, TGA, XRD, PSA, DSC, and EDX.

The formation of Ag-NPs using *Ziziphus nummularia* leave extract was confirmed by UV-Visible spectroscopy. Different ratios of Ag solution were taken against fixed ratio of *Ziziphus nummularia* leave extract. The UV peaks in the range of 400 to 430 confirm its formation.

Scanning Electron Microscopic analysis was done using Hitachi S-4500 SEM machine. Thin films of the sample were prepared on SEM grid by just dropping a very small amount of the sample on the grid and gold-coated through sputter coater. Extra solution was removed using a blotting paper and then the film on the SEM grid was allowed to dry by putting it under a mercury lamp for 5 min.

Infrared spectroscopy gives information on the vibrational and rotational modes of motion of a molecule and hence is an important technique for identification and characterization of a substance. Infrared spectra were collected by using Fourier transform infrared spectrometer (IR Prestige fourier transform infrared spectrophotometer, Shimadzu, Japan) ranging from 4000 to 600 cm^{-1}.

The thermal gravimetric analysis was done using Diamond Series TG/DTA, PerkinElmer, USA, analyzer using Al_2O_3 as reference.

XRD analysis was carried out using Joel X-ray diffractometer JDX-3532 with Ni filter, using monochromatic CuKα radiation of wave length 1.5418 Å. The X-ray generator was operated at 40 KV and 30 mA. The scanning range $2\theta/\theta$ was selected. The scanning speed 10 min^{-1} was employed for precise determination.

The isothermal behavior of Ag nanoparticles was investigated using DSC (STA 449 F3) technique over a temperature range of 50–600°C in ambient air. The sample showed two types of peaks: endothermic peaks and exothermic peaks.

Particle size analyzer gives information about the size of the synthesized silver nanoparticles formed by the leaf extract of *Ziziphus nummularia*.

The EDX analysis was performed by using EDS X Sight Oxford instrument.

The antibacterial activity of extract of *Ziziphus nummularia* and nanoparticles was determined by agar well diffusion method. The MIC and MBC of extract and silver nanoparticles were checked by macro broth dilution technique [18].

The MIC and MFC of extract and silver nanoparticles were determined for selected fungi. The MBC assay plates were incubated for 96 hours while MFC assay plates were incubated for 8 days [19]. The recorded observations were matched and compared with the MIC test tube that did not show any evidence for growth after 96 h of incubating the bacteria or spore germination for the fungi after 8 days of incubation.

Standard DPPH solution was prepared by dissolving 0.039 gm of DPPH accurately weighed with the help of digital balance in 100 mL distilled methanol to give an appropriate solution of 0.039 gm/100 mL. Then the stock solutions were enclosed with the help of aluminum foil and were kept in the dark place to protect them from the light. 0.0125 grams of each leaf extract and prepared nanoparticles was accurately weighed with the help of digital balance and dissolved in methanol to give the required solutions of 25 mL (0.0125 gram/25 mL or 500 μgm/mL or 0.5 mg/mL) to get the required concentration. Then these solutions were stored as *Ziziphus nummularia* extract and prepared nanoparticles stock solutions. One solution was of 5 mL pure of each solvent +0 mL extract *Ziziphus nummularia* and prepared nanoparticles solutions, and these solutions were used as a control solution. After that, five dilute solutions were prepared from the *Ziziphus nummularia* extract and prepared nanoparticles

solution. Then we added 1 mL of stock solution of DPPH to the diluted and control solution. All these solutions were kept in dark place for 30 minutes. Then absorbance of each solution was noted at 517 nm wave length with the help of UV-Visible spectrophotometer.

Hair growth activities of extract and silver nanoparticles were also determined. Three rabbits were taken and the right limbs of all rabbits were shaved with a razor in a dimension of 1 × 3 inches. Then the shaved area was massaged with distilled water as a control, aqueous extract of *Ziziphus nummularia*, and silver nanoparticles three times a day throughout the whole week and the results were noted in the form of photographs.

3. Results and Discussions

3.1. Characterization of Silver Nanoparticles. Various approaches have been used to achieve an improved synthesis of silver nanoparticles like biological and chemical methods. Current information on the biological synthesis of silver nanoparticle exposed the potential of a number of pharmacologically imperative plant materials which have been effectively explored for the synthesis of metal nanoparticles. From the biological origins several foodstuffs are valuable in surviving humanity like they are related with their lives in several aspects like nutritional requirements and drug development. Predominantly plant contains several types of bioactive compounds, upon interaction with inorganic nanoparticles which have a propensity to be hopeful in area of technology and nanoscience [19]. In the present research work Ag-Nps were synthesized by using *Ziziphus nummularia* leaves extract as a reducing and capping agent. Prepared nanoparticles were then characterized by UV-Visible spectrophotometry, FTIR, SEM, TGA, XRD, PSA, DSC, and EDX. The antibacterial, antifungal, antioxidant, and hair growth properties were determined for both leaves aqueous extract and nanoparticles.

3.2. Optimization of Ratio of Silver Solution and Leaves Extract for Synthesis of Ag-NPs. Plant extract showed excellent reducing and stabilizing ability due to the presence of organic compounds that helped in the reduction of Ag^{+3} to Ag^{0}. To find out optimized ratio of silver nitrate and *Ziziphus* leaves extract (reducing agent) solutions, reactions were carried out with different concentrations of 1 mM silver nitrate solution and fixed concentration of leaves extract solution. The color pattern of these reaction mixtures was different which was associated with formation of Ag-NPs. The color patterns of different ratios reaction mixtures are shown in Figure 1. UV-Visible spectroscopy results confirmed the existence of Ag because of the particular absorption peak in the region of 400–430. The ratio, which provided best result with sharpest absorption peak, was selected as optimum ratio, which was 1 : 12. Figure 2 shows the UV-Visible peaks patterns of different ratio solution of silver and leaves aqueous extract. It is evident from Figure 2 that Ag-NPs stabilized with *Ziziphus nummularia* leaves extract have different shapes and sizes peaks. The shapes and size of the peaks change as the concentration of Ag solution is changed. Absorbance

Figure 1: Color patterns of different ratios of reaction mixtures of silver solution and leaves extract solutions.

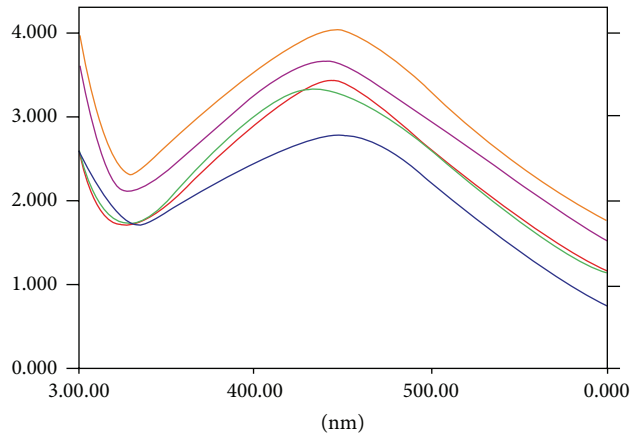

Figure 2: UV-Visible spectra of silver nanoparticles.

maximum of Ag-NPs depends upon the concentration of Ag solution. Maximum absorbance has been shown by 1 : 12 ratio of Ag solution and *Ziziphus nummularia* leaves extract. The uppermost yellow line peak is optimum ratio peak.

3.3. SEM Analysis of Silver Nanoparticles. SEM analysis showed an image of high density Ag-NPs synthesized by *Ziziphus nummularia* leaves extract and is shown in Figure 3. The white individual spots present in the SEM photograph are silver nanoparticles while the larger spots are the aggregate of silver nanoparticles. The spherical and uniform Ag-NPs have been observed with diameter ranging from 4 nm to 6.5 nm, most of silver nanoparticles present having diameter 5.2 nm. The capping agent indicates the stabilization of the nanoparticles because they were not in direct contact even in the aggregated condition. During SEM measurements the larger silver nanoparticles may be due to the aggregation of the smaller ones.

3.4. FTIR Spectroscopy. Figure 4 shows Fourier transform infrared spectroscopy of Ag-Nps. In order to ascertain the purity and nature of the metal nanoparticles infrared study was carried out. The IR spectrum consists of two regions: functional group region and fingerprint region. The organic compound gives absorption band in functional group region while the metal normally gives absorption spectra

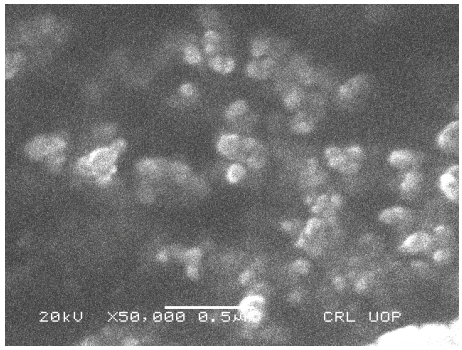

Figure 3: SEM photograph of silver nanoparticles.

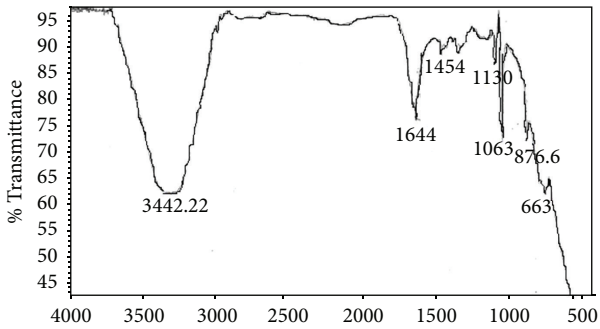

Figure 4: FTIR photograph of silver nanoparticles.

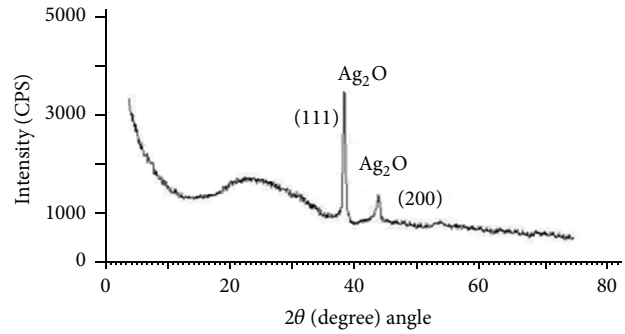

Figure 5: XRD pattern of Ag nanoparticle.

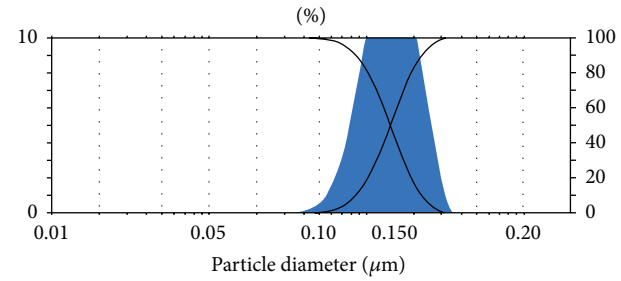

Figure 6: PSA photograph of silver nanoparticles.

in fingerprint region arising from the atomic vibrations of the molecules. The peak that was observed at 3442.22 cm^{-1} represents O-H group due to the stretching and deformation, respectively, assigned to the water adsorption on the surface of metal. Similarly the peaks occur at 1644 cm^{-1}, 1454 cm^{-1} and 1130 cm^{-1}, 1063 cm^{-1}, and 876.6 cm^{-1} indicating different functional groups that are present in the synthesized particle indicating that it can be used for various application purposes. The metal oxides frequencies observed at 668 cm^{-1} for the respective particles are according to the literature values and similarly FTIR studies of silver nanoparticles reported by Singho and his coworkers [19] favor the results.

3.5. XRD Analysis. Figure 5 shows the X-ray diffraction pattern of nanoparticles. All the diffraction peaks of sample keep up a correspondence to the typical face centered cubic (FCC) structure of silver nanoparticles (a = 0.407 nm) [20]. By using Scherrer equation 3.1 average particle size of silver nanoparticles was found to be 5.4 nm. Consider

$$D = \frac{K\lambda}{\beta \cos\theta}, \quad (1)$$

where D is the mean size, K is the constant (0.94), λ is the wavelength of X-ray, β is the excess line broadening, and θ is the Bragg angle. Consider

$$\beta = B - b, \quad (2)$$

where B stands for line width (radian) and b is instrument line broadening (radian) [21].

Diffraction pattern corresponds to the fact that there were no impurities present; this proves that pure silver nanoparticles were prepared.

3.6. Particle Size Analyzer. Particle size analyzer has been used to detect the size of the synthesized nanoparticle (Figure 6). Result of the particle size analysis confirmed the synthesis of Ag nanoparticles from the leaves extract of *Zizi-phus nummularia*. On analyzing the result it has been found that the synthesized particle ranges from 0.10 micrometer to 0.15 micrometer in size. The particles were analyzed based on the mass median diameter which indicates the 50% diameter of the particle comprising smaller particles. The particles were considered as spherical while being analyzed through particle size analyzer. The results obtained are in line with the range of Ag nanoparticles represented in the review paper published [22].

3.7. TGA. The thermal gravimetric analysis is shown in Figure 7 which gives us information about the percent weight loss of silver nanoparticles upon increasing temperature. To decompose the silver nanoparticles the sample is heated from 20°C to 160°C; at 40°C the decomposition of sample starts and its size decreases gradually up to 93.6°C. Initially the size of the sample was 8.416 mg but when the temperature was increased the sample size and weight decreased due to removing of moisture from the nanoparticles up to 0.0124 mg at 93.6°C; after that the size of the sample remains constant and no further weight loss occurs.

3.8. DSC Analysis. The isothermal behavior of Ag nanoparticles has been investigated using DSC technique over a

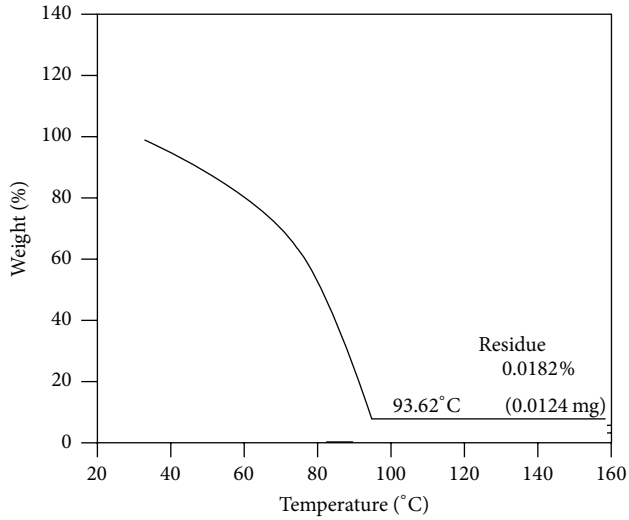

Figure 7: TGA photograph of silver nanoparticles.

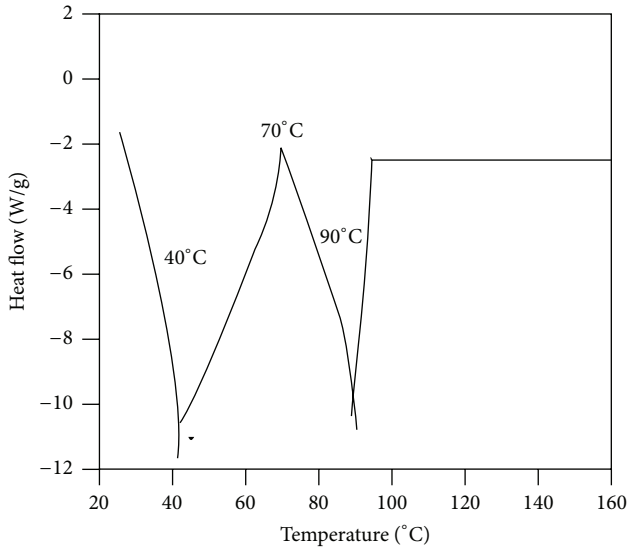

Figure 8: DSC photograph of silver nanoparticles.

temperature range of 20–160°C in ambient air. Figure 8 shows DSC curve of Ag nanoparticles. The various exothermic peaks occur at 40°C, 70°C, 90°C, and 93°C. These peaks clearly indicate that the gradual loss of water starts from the surface of nanoparticles at 40°C up to 93°C and after that the size of nanoparticles remains constant up to 160°C which gives us information about the stability of silver nanoparticles.

3.9. EDX Analysis. EDX spectrophotometer analysis established the existence of element Ag signal of Ag-Nps. EDX analysis revealed strong signal of Ag region and is in Figure 9. Metal silver nanocrystals generally show typical optical absorption peak approximately at 3.7 kev. There were other peaks for C and O suggesting that they are mixed precipitates present in the plant extract.

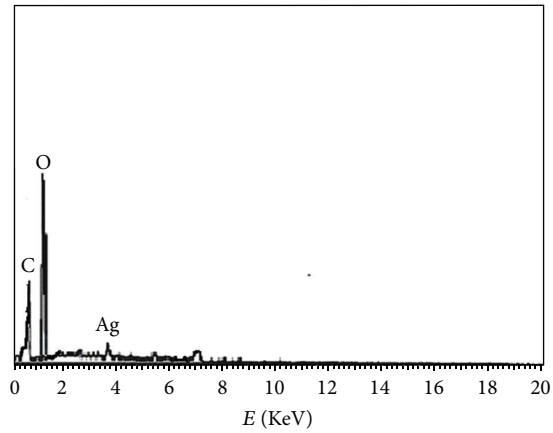

Figure 9: EDX spectrum of silver nanoparticles.

Table 1: The antibacterial activity of the tested aqueous extract of *Ziziphus nummularia* and silver nanoparticles.

Bacteria	Aqueous extract	Silver nanoparticle suspension
E. coli	10.5	17.5
P. aeruginosa	10	17
Staphylococcus aureus	8	18
S. typhi	14	21
B. cereus	10	16

3.10. Antibacterial Activities of Extract and Silver Nanoparticles. Antibacterial activity of aqueous leaf extract was determined by well diffusion method for *Salmonella typhi*, *B. cereus*, *Staphylococcus aureus*, *E. coli*, and *P. aeruginosa*. The cultures were inoculated by spread plate method. The same procedure was followed for the determination of antibacterial activity of silver nanoparticles of *Ziziphus nummularia*. The plates were then incubated for 24 hours at 37°C.

Table 1 data shows that leaf aqueous extracts are found less effective as compared to nanoparticles of *Ziziphus nummularia* plant. The nanoparticle has shown more inhibition zones against different types of bacteria while leaf extract has shown fewer inhibition zones. The nanoparticles showed 17.5 mm zone of inhibition against *E. coli*, while leaf extract showed 10.5 mm zone of inhibition against the mentioned bacteria. When we used *Staphylococcus aureus* bacteria the nanoparticles showed 18 mm zone of inhibition while leaf extract showed 8 mm zone of inhibition; similarly the nanoparticles showed 17 mm zone of inhibition against *P. aeruginosa* bacteria but leaf extract showed 10 mm zone of inhibition against *P. aeruginosa* bacteria. The nanoparticles have shown 16 mm zone of inhibition against *B. cereus* bacteria, while leaf extract showed 10 mm zone of inhibition against *B. cereus* and the nanoparticle shows 21 mm zone of inhibition against *S. typhi* bacteria, while leaf extract shows 14 mm zone of inhibition against *S. typhi*.

Table 2: Antifungal activity of tested aqueous leaf extract of *Ziziphus nummularia* and silver nanoparticle.

Fungus	Aqueous extract	Silver nanoparticle suspension
A. niger	13	12
A. flavus	7	13
Candida albicans	8	18

Table 3: The MIC and MBC activity in μg/mL of *Ziziphus nummularia* and silver nanoparticles.

Bacteria	MIC	MBC	MIC	MBC
	Aqueous extract		Silver nanoparticles	
E. coli	210	450	90	190
P. aeruginosa	190	370	70	130
Staphylococcus aureus	240	450	95	170
S. typhi	120	240	65	90
B. cereus	200	390	80	135

3.11. Determination of Antifungal Activities. Antifungal activity of the synthesized silver nanoparticles was determined, using the agar well diffusion assay method.

The data of Table 2 show that the comparison of leaf extract and nanoparticle of *Ziziphus nummularia* plant against different types of fungus of the nanoparticle has found more zones of inhibition against fungi as compared to leaf extract. For *Candida albicans* fungi the nanoparticles of leaf extract showed 8 mm zone of inhibition while silver nanoparticles show 18 mm zone of inhibition. The leaf extract shows 13 mm zone of inhibition against *A. niger* fungi while silver nanoparticle showed 12 mm zone of inhibition. As shown in the table the nanoparticle of leaf extract showed 7 mm zone of inhibition against *A. flavus* fungi but silver nanoparticles show 13 mm zone of inhibition.

3.12. The MIC and MBC Activity of Ziziphus nummularia and Silver Nanoparticles. Table 3 shows the MIC and MBC activity of *Ziziphus nummularia* and silver nanoparticles against various bacterial strains. The MIC against *E. coli* was 210 μg/mL for leaf extract while that of silver nanoparticles was 90 μg/mL, similarly the MBC for the same bacteria was 450 μg/mL in leaf extract while that of silver nanoparticles was 190 μg/mL. The MIC against *P. aeruginosa* was 190 μg/mL in leaf extract while that of silver nanoparticles was 70 μg/mL; similarly the MBC for the same bacteria was 370 μg/mL for leaf extract while that of silver nanoparticles was 130 μg/mL. The MIC against *Staphylococcus aureus* was 240 μg/mL for leaf extract while that of silver nanoparticles was 170 μg/mL. The MIC against *S. typhi* was 120 μg/mL in leaf extract while that of silver nanoparticles was 65 μg/mL. Similarly the MBC for the same bacteria was 240 μg/mL for leaf extract while that of silver nanoparticles was 90 μg/mL. The MIC against *B. cereus* was 200 μg/mL for leaf extract while that of silver nanoparticles was 80 μg/mL. Similarly the MBC for the same bacteria was 390 μg/mL for leaf extract while that of silver nanoparticles was 135 μg/mL. The above value shows that silver nanoparticles were more effective as compared to leaf extract.

Table 4: The MIC and MFC values in μg/mL of *Ziziphus nummularia* and silver nanoparticles.

Fungus	MIC	MFC	MIC	MFC
	Aqueous extract		Silver nanoparticles	
A. niger	350	560	120	170
A. flavus	430	510	150	180
Candida albicans	280	380	95	130

Table 5: Free radical scavenging activity of the tested aqueous leaves extract of *Ziziphus nummularia* silver nanoparticles.

Concentration	20 ppm	40 ppm	60 ppm	80 ppm	100 ppm
% RSA (extract)	88.76	89.67	90.85	91.39	92.92
% RSA (NPs)	98.15	95.89	95.44	97.50	98.15

3.13. The MIC and MFC Activity of Ziziphus nummularia and Silver Nanoparticles. Table 4 shows the MIC and MFC activity of *Ziziphus nummularia* and silver nanoparticles against various fungal strains. The MIC against *A. niger* was 350 μg/mL for leaf extract while that of silver nanoparticles was 120 μg/mL and in the same way the MFC for the same fungus was 560 μg/mL for leaf extract while that of silver nanoparticles was 170 μg/mL. The MIC against *A. flavus* was 430 μg/mL for leaf extract while that of silver nanoparticles was 150 μg/mL. Similarly the MFC for the same fungal strain was 510 μg/mL for leaf extract while that of silver nanoparticles was 180 μg/mL. The MIC against *Candida albicans* was 280 μg/mL in leaf extract while that of silver nanoparticles was 95 μg/mL; similarly the MFC for the same tested fungi was 380 μg/mL for leaf extract while that of silver nanoparticles was 130 μg/mL. The above value shows that silver nanoparticles are more effective as compared to the leaf extract.

3.14. Antioxidant Activity of Leaf Extract and Silver Nanoparticles. Free radical scavenging activity of leaves extract *Ziziphus nummularia* and silver nanoparticles is shown in Table 5. It is evident from the table that free radical scavenging activity of the extract and nanoparticles increases with increase in concentration of active components. Comparatively NPs showed enhanced antioxidant activity.

3.15. Hair Growth Activity. To identify the hair growth activities of distilled water, leaf extract, and silver nanoparticles, 1×3 cm part on each rabbit right leg was shaved with razor and photographs were taken from the shaved parts of rabbits in the beginning and at the end of experiments (Figure 10). The photograph showed that the rabbit shaved part massaged with silver nanoparticles has better result as compared to leaf extract and distilled water.

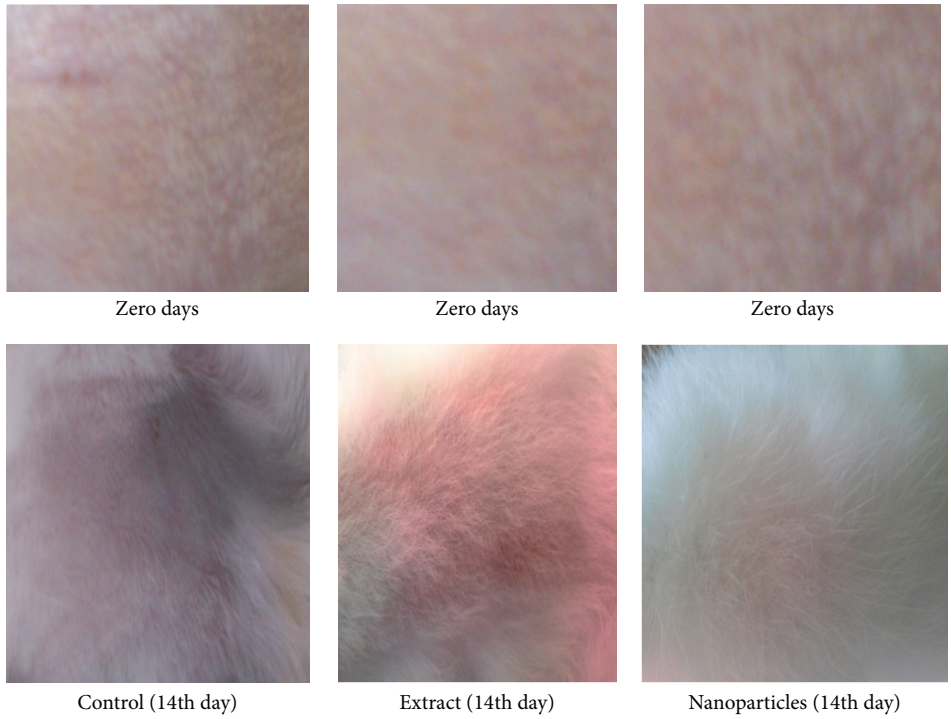

Figure 10: Hair grow activity of leaf extract and silver nanoparticles of *Ziziphus nummularia*.

4. Conclusions

In the present study silver nanoparticles were synthesized by biological synthesis. UV-Visible spectroscopy results confirmed the existence of Ag because of the particular peak in the region of 400–430. The SEM analysis confirmed spherical and uniform Ag-NPs with diameter ranging from 30 nm to 85 nm. The EDX analysis revealed strong signals in the silver reigon and confirmed the formation of silver nanoparticles. The antioxidant potential and antifungal and antimicrobial potential of the leaf extract and silver nanoparticles were determined. The antibacterial, antifungal, and antioxidant properties were found to be better for the silver nanoparticles than the aqueous leaf extract of *Ziziphus nummularia*. The MIC, MBC, and MFC of plant extract and prepared silver nanoparticles were also tested. Every time, the prepared silver nanoparticles were found to be better than the leaf extract of *Ziziphus nummularia*. The hair growth properties of plant extracts and their respective nanoparticles were observed and compared. The silver nanoparticles give good result as compared to leaf extract of *Ziziphus nummularia*.

Competing Interests

The authors declare that they have no conflict of interests.

References

[1] H. Li and L. J. Rothberg, "DNA sequence detection using selective fluorescence quenching of tagged oligonucleotide probes by gold nanoparticles," *Analytical Chemistry*, vol. 76, no. 18, pp. 5414–5417, 2004.

[2] C. O. Tettey, P. C. Nagajyothi, S. E. Lee et al., "Anti-melanoma, tyrosinase inhibitory and anti-microbial activities of gold nanoparticles synthesized from aqueous leaf extracts of *Teraxacum officinale*," *International Journal of Cosmetic Science*, vol. 34, no. 2, pp. 150–154, 2012.

[3] R. Shukla, V. Bansal, M. Chaudhary, A. Basu, R. R. Bhonde, and M. Sastry, "Biocompatibility of gold nanoparticles and their endocytotic fate inside the cellular compartment: a microscopic overview," *Langmuir*, vol. 21, no. 23, pp. 10644–10654, 2005.

[4] J. C. Sung, B. L. Pulliam, and D. A. Edwards, "Nanoparticles for drug delivery to the lungs," *Trends in Biotechnology*, vol. 25, no. 12, pp. 563–570, 2007.

[5] D. K. Lee and Y. S. Kang, "Synthesis of silver nanocrystallites by a new thermal decomposition method and their characterization," *ETRI Journal*, vol. 26, no. 3, pp. 252–256, 2004.

[6] A. J. Christy and M. Umadevi, "Synthesis and characterization of monodispersed silver nanoparticles," *Advances in Natural Sciences: Nanoscience and Nanotechnology*, vol. 3, no. 3, 2012.

[7] M. Sakamoto, M. Fujistuka, and T. Majima, "Light as a construction tool of metal nanoparticles: synthesis and mechanism," *Journal of Photochemistry and Photobiology C: Photochemistry Reviews*, vol. 10, no. 1, pp. 33–56, 2009.

[8] A. K. Suresh, D. A. Pelletier, W. Wang et al., "Silver nanocrystallites: biofabrication using *Shewanella oneidensis*, and an evaluation of their comparative toxicity on gram-negative and gram-positive bacteria," *Environmental Science and Technology*, vol. 44, no. 13, pp. 5210–5215, 2010.

[9] K. L. Kelly, E. Coronado, L. L. Zhao, and G. C. Schatz, "The optical properties of metal nanoparticles: the influence of size, shape, and dielectric environment," *Journal of Physical Chemistry B*, vol. 107, no. 3, pp. 668–677, 2003.

[10] J. T. Nurmi, P. G. Tratnyek, V. Sarathy et al., "Characterization and properties of metallic iron nanoparticles: spectroscopy,

electrochemistry, and kinetics," *Environmental Science and Technology*, vol. 39, no. 5, pp. 1221–1230, 2005.

[11] K.-H. Cho, J.-E. Park, T. Osaka, and S.-G. Park, "The study of antimicrobial activity and preservative effects of nanosilver ingredient," *Electrochimica Acta*, vol. 51, no. 5, pp. 956–960, 2005.

[12] Z. Deng, M. Chen, and L. Wu, "Novel method to fabricate SiO_2/Ag composite spheres and their catalytic, surface-enhanced raman scattering properties," *Journal of Physical Chemistry C*, vol. 111, no. 31, pp. 11692–11698, 2007.

[13] H. Wang, X. Qiao, J. Chen, and S. Ding, "Preparation of silver nanoparticles by chemical reduction method," *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, vol. 256, no. 2-3, pp. 111–115, 2005.

[14] H. Wei, J. Li, Y. Wang, and E. Wang, "Silver nanoparticles coated with adenine: preparation, self-assembly and application in surface-enhanced Raman scattering," *Nanotechnology*, vol. 18, no. 17, Article ID 175610, 2007.

[15] X. Jia, X. Ma, D. Wei, J. Dong, and W. Qian, "Direct formation of silver nanoparticles in cuttlebone-derived organic matrix for catalytic applications," *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, vol. 330, no. 2-3, pp. 234–240, 2008.

[16] R. Bhattacharya and P. Mukherjee, "Biological properties of 'naked' metal nanoparticles," *Advanced Drug Delivery Reviews*, vol. 60, no. 11, pp. 1289–1306, 2008.

[17] D. D. Evanoff Jr. and G. Chumanov, "Synthesis and optical properties of silver nanoparticles and arrays," *ChemPhysChem*, vol. 6, no. 7, pp. 1221–1231, 2005.

[18] NCCLS (National Committee for Clinical Laboratory Standards), *Methods for Dilution Antimicrobial Susceptibility Tests for Bacteria that Grow Aerobically*, vol. 13, no. 25, Approved Standard, M7-A3. NCCLS, Villanova, Pa, USA, 3rd edition, 1993.

[19] N. D. Singho, N. A. C. Lah, M. R. Johan, and R. Ahmad, "FTIR studies on silver-poly (methylmethacrylate) nanocomposites via in-situ polymerization technique," *International Journal of Electrochemical Science*, vol. 7, no. 6, pp. 5596–5603, 2012.

[20] S. Krehula and S. Musić, "Formation of magnetite in highly alkaline media in the presence of small amounts of ruthenium," *Croatica Chemica Acta*, vol. 80, no. 3-4, pp. 517–527, 2007.

[21] M. Sundrarajan and M. Ramalakshmi, "Novel cubic magnetite nanoparticle synthesis using room temperature ionic liquid," *E-Journal of Chemistry*, vol. 9, no. 3, pp. 1070–1076, 2012.

[22] X. Li, H. Xu, Z.-S. Chen, and G. Chen, "Biosynthesis of nanoparticles by microorganisms and their applications," *Journal of Nanomaterials*, vol. 2011, Article ID 270974, 16 pages, 2011.