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Green Synthesis and Characterization of Silver Nanoparticles Using Neem Leaf Extract (*Azadirachta Indica*)

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Abstract

Although the green synthesis of silver nanoparticles (AgNPs) has only lately been acknowledged, the use of silver and silver salts dates back to the dawn of human civilization. Silver salt and neem leaf aqueous extract were used to create AgNPs. Utilizing the reducing and capping properties of the bioactive chemicals found in the neem leaf extract, the technology uses a simple, environmentally friendly synthesis procedure. This research aims to carry out the synthesis of AgNPs using the Azadirachta indica leaf extract as reducing agent. The produced silver nanoparticles were characterized using a variety of techniques, including Transmission Electron Microscope (TEM), X-ray Diffraction (XRD), and UV-Vis adsorption spectroscopy. A noticeable adsorption peak at 383 nm was seen in the UV-Vis adsorption spectrum, indicating the distinctive surface Plasmon resonance of the silver nanoparticles. Their mild agglomerative spherical shape was demonstrated by the TEM image, and their crystalline nature was confirmed by the XRD image. To determine the substance responsible for the reduction of the silver ions, FTIR analysis was performed. The FTIR spectra reveals that the AgNPs were also capped with phytochemicals from the leaf extract the characterizations results confirms the successful formation of silver nanoparticles.

Keywords: Nanoparticles, green synthesis, Neem leaf, silver nanoparticle.

Introduction

In modern science and technology, nanoparticles minuscule objects with sizes on the nanometer scale have become a revolutionary new frontier. Nanoparticles differ from their macroscopic counterparts in that matter at this scale displays

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special and frequently surprising features. Nanoparticles, whose diameters usually range from 1 to 100 nanometers, are found in a domain dominated by surface phenomena and quantum effects, the importance of nanoparticles is multidisciplinary, changing sectors and providing novel answers to persistent problems. They improve the performance of materials and add new features in materials science applications that range from electronics to catalysis [1].

Nanoparticles have transformed medication delivery in medicine by allowing for precise targeting and controlled release, which increases the effectiveness of therapeutic medicines and lessens their negative effects [2]. Nanoparticles, by definition, are particles with dimensions in the nanometer range, typically between 1 to 100 nanometres. This diminutive size imparts unique properties compared to bulk materials. At the nanoscale, quantum effects become increasingly significant, leading to alterations in the physical, chemical, and biological behaviors of materials, mechanical strength, size dependence, huge surface area, quantum effect, thermal conductivity, and chemical reactivity are the characteristics that set nanoparticles apart. There are several other physicochemical properties [3].

Furthermore, according to environmental science, nanoparticles are essential to remediation efforts because they provide a potent toolkit for preventing pollution and slowing down environmental deterioration; also they are essential in catalytic processes and pollution abatement technologies due to their remarkable surface area-to-volume ratio and reactivity [4].

Their quantum properties open up possibilities for novel computing paradigms and revolutionary advances in telecommunications. In this rapidly advancing field, interdisciplinary collaboration is paramount, as researchers, engineers, and innovators work in concert to unlock the full potential of nanoparticles [5]. Nanoparticles can be synthesized by various methods such as chemical and photochemical reactions in reverse micelles, thermal decomposition, electrochemical, sonochemical, microwave assisted process, and also by biological methods [6]. Among these methods, biological processes that are based on bacteria, fungi, bio-derived chemicals and plant extracts are considered as safe and economically viable for the nanomaterial fabrication [7].

Furthermore, the neem leaf extract imparts a stabilizing effect, preventing agglomeration and ensuring the colloidal stability of the silver nanoparticles. This natural capping agent confers biocompatibility to the nanoparticles, rendering them suitable for a myriad of applications, particularly in biomedicine and environmental remediation [8] The Silver nanoparticles were synthesized using *Azadirachta indica* extract. Current nanotechnology research uses a lot of chemical which are quite often toxic and flammable. Plant extract produces best capping

material for stabilization of silver nanoparticles, researchers have discovered that phytochemicals present in plant extract are responsible for metal ion reduction and capping of the newly formed particles during their growth processes, alkaloids, terpenoids, ketones, amides, aldehydes, polyphenols and carboxylic acids present in plants are good promoters for bio-reduction of metal ions into nanoparticles and also for supporting their subsequent stability [9].

This study intends to utilize the leaf extract of *Azadirachta indica*, often referred to as neem, a member of the Meliaceae family, for the green synthesis of silver nanoparticles. The acqueous neem extract is used in the synthesis of various nanoparticles such as gold, zinc oxide, etc.

Materials and Methods

Materials

Silver Nitrate ($AgNO_{3)}$ was purchased from Central Drug House, New Delhi, India. 1 M ethanol with 99% purity was purchased from Central Drug House (P) Ltd New Delhi India. The UV-Vis spectral analysis was done by using Shimadzu UV-Vis spectrophotometer (UV-1800), UV-Vis absorption spectrophotometer with a resolution of 1 nm between the absorption ranges of 200-700 nm was used to investigate the formation of AgNPs. The FT-IR spectra was recorded using Perkin Elmer FT-IR instrument operating at a resolution of 400-4000 cm^{-1} in % transmittance mode. FT-IR analysis was mainly performed to study the functional group present in the reduction of Ag^{+} to Ag^{0}.

Method

Sample collection

The Fully matured leaves of *Azadirachta Indica* were collected from Federal University Dutse, Faculty of science beside Microbiology Laboratory. In October 2023.Debris and other contaminated organic material were removed from their surface using running tap water then distilled water and air dried at room temperature.

Preparation of Sample

The dried *Azadirachta indica* leaves were cut finely into smaller pieces, then, the sample was prepared by taking 20 g of the leaves in to a beaker containing 200 cm^3 of distilled water and boiled for 30 minutes, the extract was cooled down and filtered using a Whatmann filter paper and the clear extract was stored at 4^{o}C In a fridge for further use [10].

Green Synthesis of Silver Nanoparticles

Aqueous solution of silver nitrate was prepared at a concentration of 0.1 M in an Erlenmeyer flask and used for the synthesis of silver nanoparticles. 1 mL and 2 mL of the leaf extract were added to 10 ml of silver nitrate solution keeping its concentration at 0.1 M. This setup was incubated in a dark chamber to minimize photo-activation of silver nitrate at room temperature. Reduction of Ag^{+} to Ag^{0} was confirmed by color change of the solution from yellow to brown, and UV-Vis

analysis was carried out for the absorbance of the AgNPs. For the collection of AgNPs, the solution was centrifuged for 25 minutes. at 5000 rpm, then the pellets (AgNps) were washed with distilled water then with 1M ethanol to remove the impurities, then obtained AgNPs was dried at 50^0C in an Oven and stored for further characterization [11].

Result and Discussion

Characterizations of silver nanoparticles

Visual observation

Upon addition of neem leaf extract to silver nitrate solution, a visible color change from pale yellow to dark brown was observed as in figure 1 and 2 which indicates the formation of AgNPs. The appearance of brown color could be explained due to the surface plasmon vibration effect and change of Ag^+ ions to Ag^0 by aqueous extracts, which is characteristics property of silver nanoparticles [12]. After incubation a complete color change was observed which indicates that the silver salt was completely reduced to AgNPs. The natural agent such as flavonoids and terpenoids present in the neem extract were responsible for the reduction of silver salt to its corresponding nanoparticles [12]. The synthesis of novel metals NPs has been subjected for many applied researches due to its unique properties.



(a) Neem leaf



(b) (b) Neem leaf extract

Figure 1: Neem leaves and extract with $AgNO_3$

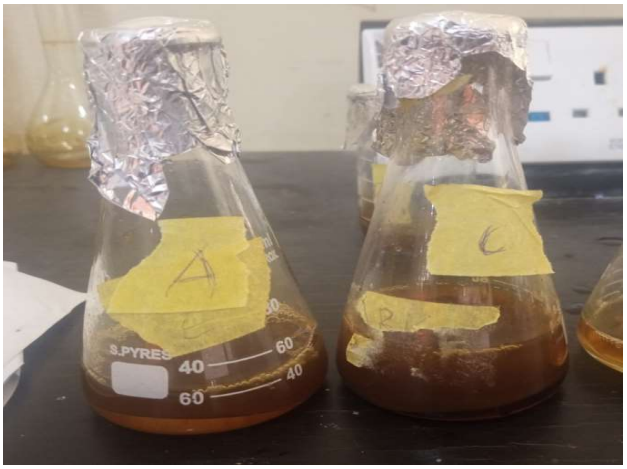


Figure 2: Synthesized silver nanoparticles

UV-Vis spectroscopy analysis

The samples were observed under UV-Vis spectrophotometer for its maximum absorbance and wavelength to confirm the reduction of Silver nitrate. Silver nanoparticles were synthesized at different concentration of leaf extract such as 1, and 2 using 1 mM similar those reported in the literature [13]. The maximum peak was found to be 383 nm for AgNPs. From study carried out by [14]. the peak value for AgNPs was 351 nm. The maximum peak value of 420 was reported for AgNPs in the study done by [14].

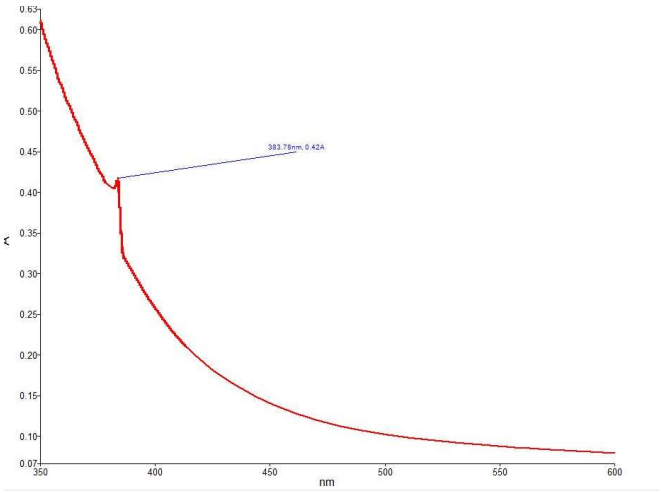


Figure 3: UV-Vis spectra; showing absorbance with 1 mL of plant extract

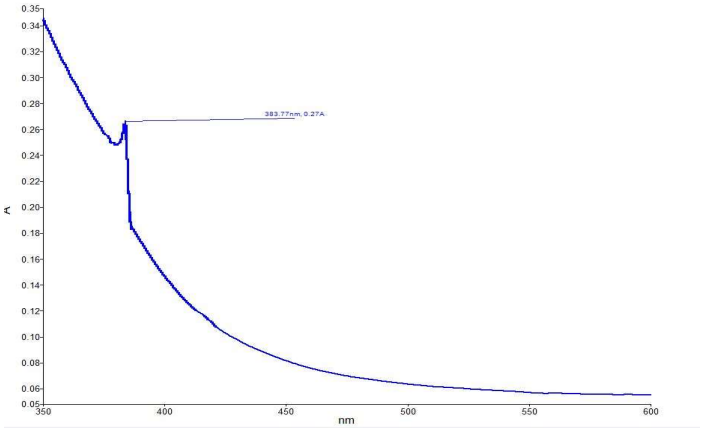


Figure 4: UV-Vis spectra; showing absorbance with 2 mL of plant extract

FT-IR analysis

The FTIR spectrum was taken in the IR region of 400-4000 cm^{-1}. Infrared spectroscopy gives information on the vibrational and rotational modes of motion of a molecule and hence an important technique for identification and characterization of a substances. The dual role of plant extract as a reducing and capping agent and presence of some functional groups was

confirmed by FTIR analysis of Neem Leaves (figure: 5). The following peaks are the major peaks observed in the neem leaves; A broad band at 3279 cm^{-1} may be assigned to O-H bond stretching, while the peak at 2918 cm^{-1} may be assigned to C-H stretching vibration of alkanes, a peak at 2851 cm^{-1} indicates the H–C=O of aldehyde and the peak at 1640 cm^{-1} corresponds to C=O stretching and the peak at 1611 cm^{-1} indicates the N-H bending of amines, also the peak at 1033 cm^{-1} indicates C-O stretching of alkyl ether.

Biologically synthesized silver nanoparticles (figure: 6) shows a similar set of peaks, the major peak observed are; Broad peak of O-H at 3268 cm^{-1} which override the C-H stretch peak at 2918 cm^{-1}, the peak at 1562 cm^{-1} correspond to N-H bending of amine and the peak at 1022 cm^{-1} is due to C-O stretching of alkyl ether. In Conclusion, the reappearance of O-H, C-H, N-H, and C-O peaks in the FTIR spectrum of silver nanoparticles which are equally visible in the FTIR of neem leaves extract, confirmed that the biomolecules in the neem leaves extract took part and are present in the synthesized silver nanoparticles. The observed amide C=O stretching vibration may be due to the presence of amide group, raised by carbonyl stretch of proteins, whereas OH, C-O, C=C, stretch may be attributed to phytochemicals such as alkaloids, terpenoids, flavonoids, phenolics, etc. which are abundantly present the leaf extract. Therefore, FT-IR analysis demonstrates the presence of proteins and phytochemicals involved in capping AgNPs hence providing stability to them [15]. Therefore, FT-IR analysis of the synthesized AgNPs using neem and leaves extracts showed that these functional groups from the aqueous extract of neem leaf were responsible for the reduction Ag^{+} to Ag^{0}, the AgNPs synthesis and stabilization, and are present on the surface of the synthesized nanoparticles.

From the previous study, the observed peak at 1022 cm^{-1} denotes –C-O-C linkage or –C-O bonds. The observed peak is mainly attributed to flavonoids and terpenoids excessively present in plant extract [16].

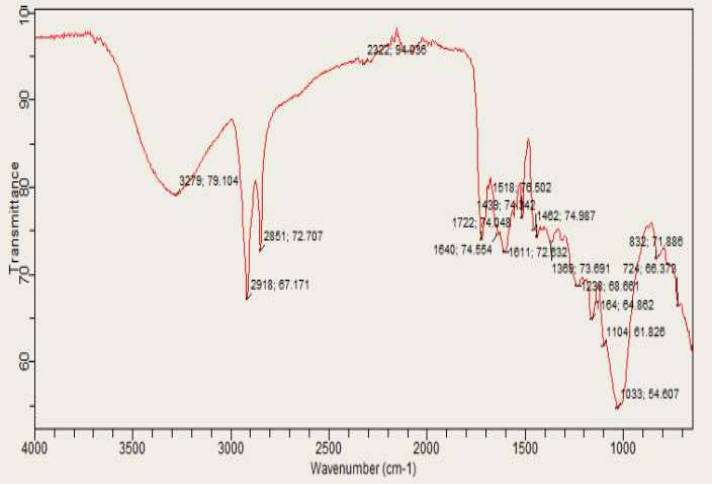


Figure 5: FTIR spectra of neem leaves

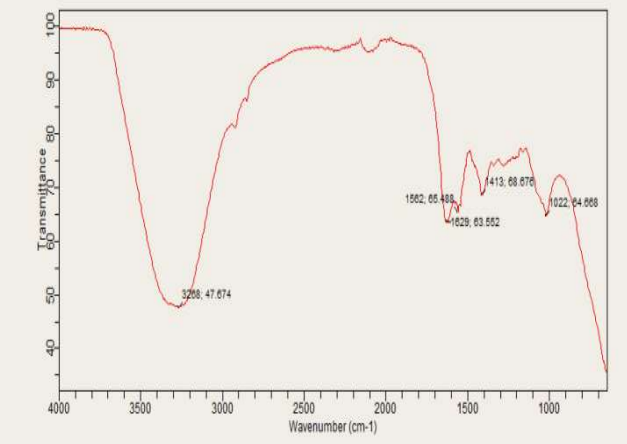


Figure 6: FT-IR spectra of synthesized silver nanoparticles

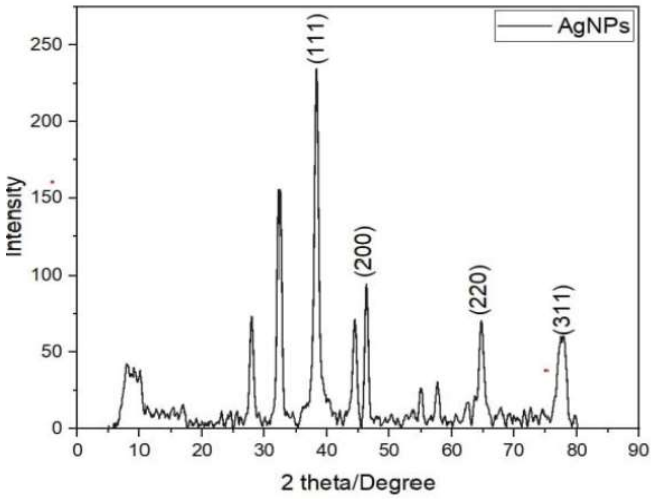


Figure 7: XRD image of the synthesized AgNPs

X-ray Diffraction analysis (XRD)

X-ray Diffraction analysis (XRD) was used to investigate the crystalline nature of the synthesized silver nanoparticles. The silver crystal planes face-centered cubic structure was observed at 2 theta angles of 38°, 47°, 64°, and 78° corresponding to the Miller indices 111, 200, 220, and 311 planes (Figure 7). Similar to the silver nanoparticles crystal planes reported by [17]. This reveals that the nanoparticles are crystalline and also confirms that they are capped by biomolecular compounds which were responsible for the reduction of silver ions.

Transmission electron microscope (TEM) analysis

The size, shape and morphololgy of the biosynthesized silver nanoparticles were determined using a transmission electron microscope (TEM). It showed that silver nanoparticles are well dispersed and most of the AgNPs were spherical in shape with mean particle size estimated 15 nm as shown in (figure 8) similar to the previous study reported by [18]. Also the uniform and spherical nature of the nanoparticles fits the UV-visible spectrum's SPR band shape.

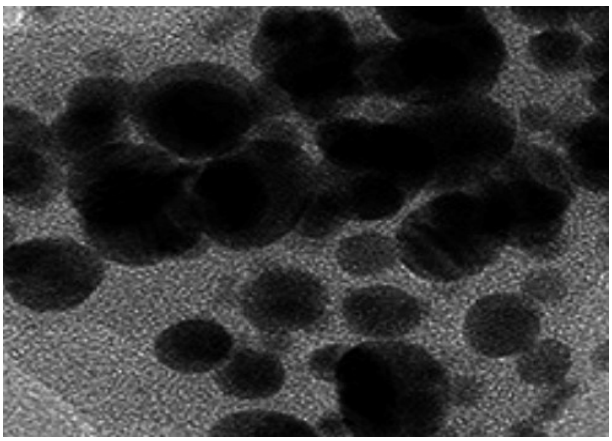


Figure 8: TEM of the synthesized AgNPs

Conclusions

Silver nanoparticles were successfully synthesized from its silver salt using neem leaf extract and characterized using various analytical techniques, UV-Vis spectrum reveled an adsorption peak at 383 nm, the spherical shape and the crystalline nature were identified using TEM and XRD respectively. FTIR spectra also showed that the phytochemicals present in the leaf extract extract probably, flavonoids and terpenoids were responsible for capping and stabilization of the silver nanoparticles. The reaction pathway meets all criteria for green chemical processes and demonstrates an eco-friendly, quick method for the synthesis of silver nanoparticles.

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Conflict of interest

The authors declared that there is no conflict of interest.

References

1. Saha J, Begun A, Mukharjee A, Kumar S (2017) A novel grren synthesis of silver nanoparticles and their catalytic action in reduction of Methylene Blue dye. Sustainable Environmental Resources. Doi:10.1016/j.serj.2017.04.003
2. Abdelghany, T., Al-Rajhi, A. M., Al Abboud, M. A., Alawlaqi, M., GanashMagdah, A., Helmy, E. A., andMabrouk, A. S. J. B. (2018). *Recent advances in green synthesis of silver nanoparticles and their applications: about future directions. A review*. *8*, 5-16.https://doi.org/10.1007/s12668-017-0413-3
3. Roy, P., Das, B., Mohanty, A., and Mohapatra, S. J. A. N. (2017). Green synthesis of silver nanoparticles using *Azadirachta indica* leaf extract and its antimicrobial study. *7*(8), 843-850.https://doi.org/10.1007/s13204-017-0621-8
4. Rai M, Yadav A, Gade A(2009) Silver nanoparticles as a new generation of antimicrobials. Biotechnological advancement 27(1):76-83
5. Singh, J., Dutta, T., Kim, K. H., Rawat, M., Samdarr, P., and Kumar, P. (2018), Green synthesis of metal and their oxide nanoparticle:Application for environmental Remediation. *Journal of Nanobiotechnology,* https://doi.org10.1186/s12951-018-0408-4
6. Iravani, S; Korbekandi, H; Mirmohammadi, S; Zolfaghari, B (2014). Synthesis of silver nanoparticles: chemical, physical and biological methods. *Res. Pharm. Sci. 9, 385*

7. Valli, JS; Vaseeharan, B (2012). Biosynthesis of silver nanoparticles by Cissus quadrangularis extracts, Mater. Lett. 82,171-173
8. Ahmed S, Ahmad M, Swami BL, Ikram S (2015)Plants extract mediated synthesis of silver nanoparticles for antimicrobial application: a green expertise. Journal of Advanced Resources. doi:10.1016/j.jare.2015.02.007
9. Smith, AM; Duan, H; Rhyner, MN; Ruan, and G; Nie, SA. (2006). Systematic Examination of Surface Coatings on the Optical and Chemical Properties of Semiconductor Quantum Dots. Physical Chemistry Chemical Physics. 8(33), 3895–390 https://doi.org/10.1039/b606572b
10. Ahmed S, Ullah S, Ahmed M, and Swani BL. Green synthesis of silver nanoparticle using *Azadirachta indica* aqueous leaf extract. *Journal of Radiation Research and Applied Sciences* 2015;9 (1):1-7
11. Banerjee P, Satapathy M, Mukhopahayay A, and Das P. Leaf extract mediated green synthesis of silver nanoparticles from widely available indian plant: *Synthesis characterization, antimicrobial property and toxicity analysis. Bioresour Bioprocess* 2014;1:1-10 https://doi.org/10.1186/s40643-014-0003-y
12. Obaid, A. Y., Al-Thabaiti, S. A., Al-Harbi, L. M., and Khan, Z. (2015). Extracellular bio-synthesis of silver nanoparticles. *Global Advanced Research Journal of Microbiology*, 3(8), 119-126 https://doi.org/10.1016/ j.arabjc.2014.12.035
13. Arya, G; Sharma, N; Ahmed, J, Gupta, N; Kumar, A; Chandra, R; Nimesha S (2017). Degradation of anthropogenic pollutant and organic dyes by biosynthesized silver nano-catalyst from Cicer arietinum leaves. Journal of Photochemistry & Photobiology, B: Biology 174, 90–96
14. Asmita J. Gavhane., P. Padmanabhan, Suresh P. Kamble and Suresh N.Jangle. 2012. Synthesis of silver nanoparticles using extract of neem leaf and triphala and evaluation of their Antimicrobial activities. International journal of pharmaceutical Bio Science 0975-6299.
15. Chung IM, Park I, and Seung-Hyun K, *et al* Plant-mediated synthesis of silver nanoparticles: their characteristics properties and therapeutic applications. *Nanoscale Res Lett* 2016;11(1): 1-4 https://doi.org/10.1186/s11671-016-1257-4
16. Sre, P. R., M. Reka, R. Poovazhagi, M. A. Kumar, and K. Murugesan. 2015. "Antibacterial and Cytotoxic Effect of Biologically Synthesized Silver Nanoparticles Using Aqueous Root Extract of Erythrina indica Lam." Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 135:1137-1144
17. Prathna, T. C., Chandrasekaran, N., Raichur, A. M., and Mukherjee, A. (2011). Biomimitic Synthesis of silver nanoparticles by Citrusl limon (lemon) acqueous extract and theretical prediction of particles size. *Colloids and surfaces B: Biointerfaces,* 82, 152-159 https://doi.org/10.1016/j.colsurfb.2010.08.036
18. Verma, S.K., Jha, E., Sahoo, B., Panda, P.K., Thirumurugan, A., Parashar, S.K.S. and Suar M. (2017) Mechanistic Insight into the Rapid One-Step Facilebio Fabrication of Antibacterial Silver nanoparticles from Bacterial Release and Their Biogenicity and Concentration-Dependent *in Vitro* Cytotoxicity Tocolon Cells. *RSC Adavances*, 7, 40034-40045.