Green Fabrication of Silver Nanoparticles: A Study on Structural Properties and Antimicrobial Effects

S. Sabadini, D. Febilin Bershia, S. Ajith Sinthuja and *Y. Christabel Shaji
Department of Chemistry, Holy Cross College (Autonomous), Nagercoil - 629004.
Affiliated to Manonmaniam Sundaranar University, Tirunelveli - 627012.
*Corresponding Author - Email: christabelshaji@holycrossngl.edu.in

ABSTRACT

In material sciences, one of the most prominent topics has been the study of biogenically produced nanoparticles (NPs) from plant derivatives and their potential use as sustainable catalysts. Utilizing bio nanotechnology approaches, one may produce nanoparticles and nanomaterials in an economical and ecologically responsible manner. They are employed in a variety of industries, including as electronics and healthcare. They help with diagnostic imaging and enhance the precision of medicine's drug administration. The capacity of the star apple (Chrysophyllum cainito) to biosynthesize silver nanoparticles (Ag NPs) and their use in the breakdown of dyes and antibacterial activities were confirmed by this study. The development of Ag NPs that caused the red shift and widening of SPR was validated by the existence of surface plasmon resonance at 420 nm. The results showed that lowering sugars and flavonoids was the primary source of the bio-reduction of silver ions. Additionally, the spherical shape of the nanoparticles and the properties of metallic nanocrystals were revealed by an absorption peak at around 3 keV in the energy dispersive X-ray (EDX) and scanning electron microscopy (SEM) spectra. Moreover, X-ray Diffraction (XRD) investigation confirmed that the particles were crystalline. To find possible biomolecules in charge of the bio-reduction of silver ions, Fourier Transform Infrared (FT-IR) research was performed. The bactericidal and fungicidal activity of the biosynthesized AgNPs against Gram-positive, Gram-negative, and mixed bacteria and fungi is evaluated using an antimicrobial test. As a result, the current work holds value for further investigation into the optimal antimicrobial agents and may find use in biological fields.

Keywords: *Antibacterial effect, Antifungal effect, Bio reduction, green synthesis*

1. Introduction

The green chemistry method employs natural, biodegradable, non-toxic, and environmentally benign components to produce nanomaterials and nanoparticles at a minimal cost and impact. Research on the application of metal nanoparticles—particles smaller than 100 nm—in textiles has lately accelerated and attracted interest from scientists [1-4] in contrast to bulk scale, owing to their higher surface to volume ratio, superior biological activities, and size-dependent properties. Several studies have identified silver nanoparticles because of their broad spectrum of antibacterial characteristics, minimal toxicity to normal cells, and ability to break down organic dyes [5]. Silver nanoparticles may be produced *via* a green chemistry method including plant extracts; the antibacterial properties of these particles rely on their nanoscale size [6,7]. Moreover, the work uses leaf extract from *Chrysophyllum cainito* to explore the many uses of these green-synthesized AgNPs. Their ability to act as catalysts to remove organic dyes from aqueous solutions is demonstrated by an examination of their effectiveness in dye degradation. Various analytical approaches were employed to monitor the degradation process, hence providing insights into the kinetics and efficiency of the AgNPs-mediated degradation. Furthermore, the manufactured silver nanoparticles' antibacterial capacity was evaluated against a variety of harmful microbes.

The efficacy of AgNPs in preventing the development of bacteria and fungi is determined by evaluating their antibacterial potential using known techniques [8-9]. This extensive study intends to provide important insights into the green synthesis of AgNPs, their detailed characterization, and their many uses in health care and environmental remediation. The findings highlight the potential of these environmentally friendly AgNPs as multipurpose nanomaterials with bright futures for practical and sustainable uses across a range of industries.

2. Materials and Methods

2.1 Preparation of Leaf Extracts

Fig.1 Leaf of *Chrysophyllum cainito* used for the synthesis

Fresh leaves of star apple (*Chrysophyllum cainito*) Fig. 1 free from diseases were collected from Rajakkamangalam village, Kanyakumari district. The leaves were cleaned in the running water and then with deionized water to remove dust particles if any. The leaves were dried in the shade for a week. It was then powdered finely using a mortar. About 5g of this leaf was weighed and is used for the extraction process. It was boiled with 10Ml of deionized water in a beaker for 15 minutes at 100°C.Thesolution first becomes yellow and then turned to brown colour. After cooling, the liquid was utilized to prepare silver nanoparticles by filtering it *via* Whatman filter paper No. 1.

2.2 Environmentally friendly production of silver nanoparticles

0.1N silver nitrate solution was prepared by taking 3.39g of silver nitrate. 9:1 of zinc acetate solution and leaf extract was taken and the extract was added dropwise into beaker to ensure thorough mixing. The mixture was stirred in a magnetic stirrer for about 24 hours for the bio reduction process at room temperature. The colorless solution slowly turned pale yellow colour followed by brown colour (Fig. 2). After 24 hours a black precipitate was observed at the bottom which indicated the formation of nanoparticles. To separate the nanoparticles the solution was subsequently centrifuge for 900 seconds at 10,000 rpm and washed with deionized water. The precipitate obtained was dried at room temperature and used for characterization [10].

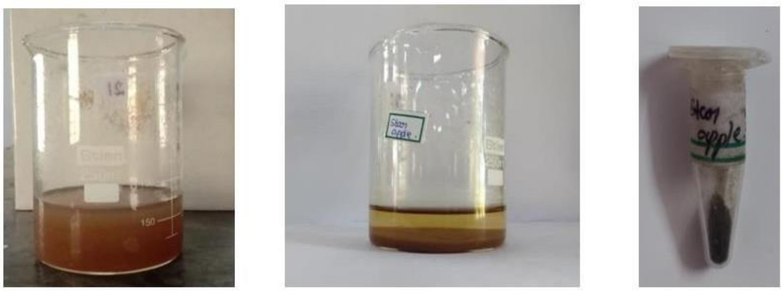

Fig. 2 Synthesized silver nanoparticle

2.3 Evaluation of nanoparticle characteristics

Using spectra of artificially produced silver nanoparticles captured by a UV-visible spectrophotometer (Perkin-Elmer 17 Lamda-45), the bio reduction of Ag^+ ions was tracked. Using the CuKα radiation and the Enraf Nonius CAD-4model of XRD, the powdered nanoparticle's X-ray diffraction pattern (k=0.154060nm) was determined. Using a Hitachi-S4800, the morphological observations of the nanoparticles were studied by SEM and EDX analysis.

3. Results and Discussion

3.1 X-ray diffraction analysis

The crystallite size was calculated using the Debye-Scherrer equation and the following formula: $D = K\lambda / \beta\cos\theta$

Where D, K, λ, β and θ corresponds to size of the crystallite, constant, X-ray wavelength, Full width at half maximum value and diffraction angle, respectively [10]. This was shown in the Table 1. Thus, the typical size of crystallites of synthesized AgNPs is 43.52 nm and suggested that the AgNPs is micro crystalline nature.

Table 1. XRD values of silver nanoparticles

Peak position	FWHM	D-Value
54.825	0.233	35.53
49.890	0.100	86.62
39.440	0.216	38.5
76.571	0.208	39.6
57.336	0.222	37.45
18.812	0.213	38.5
35.068	0.177	47.79
34.411	0.181	46.2
27.752	0.182	46.2
37.987	0.324	25.2
46.184	0.191	43.3
32.181	0.219	37.45

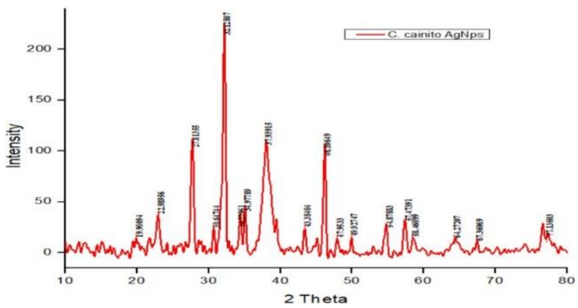

Fig. 3. XRD Spectrum of *C. cainito* AgNPs

By using the XRD pattern seen in Figure 3, it was possible to determine that the silver nanoparticles were crystalline. AgNPs' XRD pattern shows a total off our peaks at two theta angles in the diffraction peaks. 37.98°, 49.89°, 64.27° and 76.57° are attributed to the silver's face-centered cubic units, which have the following index values:(111), (200), (220),and (311). Moreover, undesignated peaks at 2θ values of 27.75°,32.18°, 6.18° and 54.82°. In addition to this XRD result, it was also revealed that the silver nanoparticles produced by biosynthesis include amorphous and organic components [11]. Prominent peaks were seen in the XRD patterns, indicating that the silver nanoparticles were well-crystalline.

3.2 UV-Visible analysis of silver nanoparticles

Absorption Spectra of the synthesized AgNPs has absorbance at 392nm, Peak broadening suggested that the tiny fragments are widely distributed (Fig. 4).

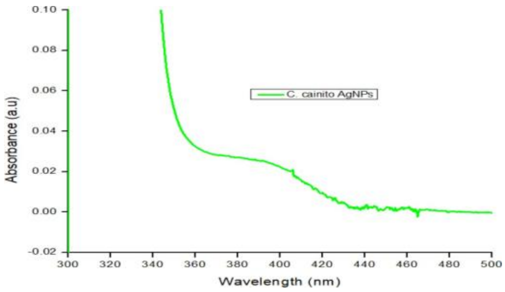

Fig. 4. UV-V is spectrum of silver nanoparticles

3.3 FT-IR Analysis of Silver nanoparticles

The FTIR spectra of the synthesized AgNPs shows bands at 3392, 3230, 2920, 2860, 2372, 1745 and 1575 cm^{-1}respectively (Fig. 5). It also confirms the bio reduction of Ag^{+} in the presence of *Chrysophyllum cainito* husk extract.

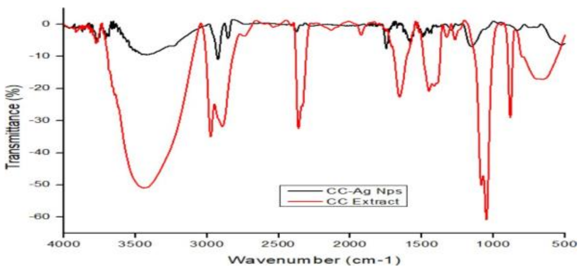

Fig. 5 FT-IR Spectrum of AgNPs and *C. cainito* leaf extract

3.4 Morphology studies (SEM)

Morphological examinations for the silver nanoparticles were carried out by using Scanning Electron Microscopy. The images (Fig. 6) display that all the prepared nanoparticles exhibit almost rod shape. Also, the obtained SEM image display the formation of nanoparticles and some leaf extract residues.

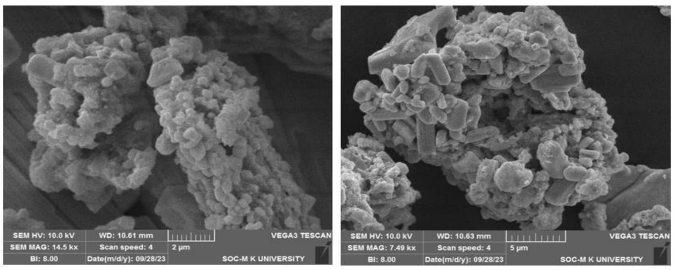

Fig. 6 SEM image of synthesized *Chrysophyllum cainito* based silver nanoparticles

3.5 EDAX Studies

The EDAX spectral image displayed the presence of metallic silver at 3KeV. The elemental dot mapping (Fig. 7) of a selected area showed up 4%-N, 24.25%-O, 71.75%-Ag of the corresponding elements

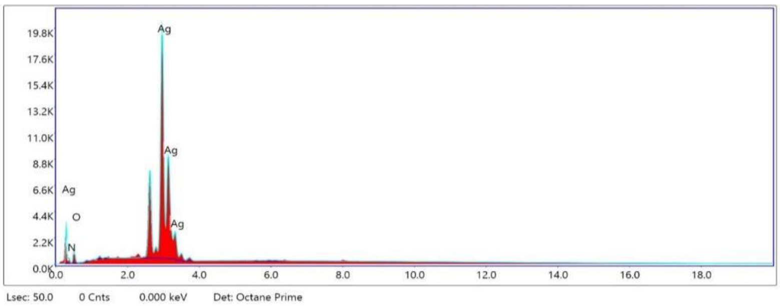

Fig.7 EDAX spectrum of C. cainito silver nanoparticles

3.6 Antimicrobial Activity

3.6.1 Zone of Inhibition of Silver nanoparticles from *Chrysophyllum cainito*

The zone of inhibition AgNPs produced using the *Chrysophyllum cainito* extract against gram-positive B. Subtilis and Gram-negative *Proteus mirabilis* were studied using Chloramphenicol(10µg) as the control (Fig. 8).

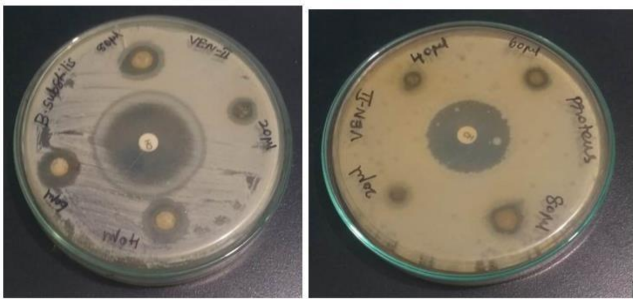

Fig. 8 Zone of Inhibition Bacillus subtilis, Proteus mirabilis

The antibacterial activity of AgNPs (100 mg) against Gram positive *B. subtilis* was greater when compared with the Gram-negative *Proteus mirabilis* shown in Table 2.

Table 2. Zone of inhibition of bacteria with varied concentration

Bacteria	20 µL	40 µL	60 µL	80 µL	Standard
***Bacillus subtilis* (Positive)**	11	15	18	18	35
***Proteus mirabilis* (Negative)**	7	9	10	12	25

The zone of inhibition AgNPs produced using the *Chrysophyllum cainito* leaf extract against *Rhizopus microsporus* and *Penicillium* were studied using Chloramphenicol (10µg) as the control (Fig. 9).

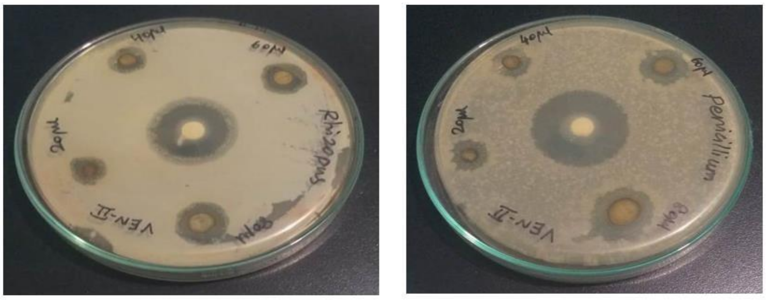

Fig. 9 Zone of inhibition *Rhizopus microsporus and Penicillium sp.*

The antifungal activity of AgNPs (100mg) against *Penicillium sp.* was greater when compared with the *Rhizopus microspores* shown in Table 3.

Table. 3 Zone of inhibition of fungi with varied concentration

Fungi	20µl	40µl	60µl	80µl	Standard
Rhizopus microsporus	12	14	16	18	20
Penicillium Sp.	123	14	16	21	30

4. Conclusion

The present investigation uses *Chrysophyllum cainito* to prepare and assess silver nanoparticles, and it looks at the antibacterial and dye degradation properties of the material. FT-IR, UV, XRD, and SEM were used to characterize the synthesised silver nanoparticles. The synthesised AgNPs exhibit a strong absorbance at 392 nm (π-π* transition) according to UV spectroscopy. It was noted that synthesizing AgNPs is an easy and convenient process. It was confirmed by FT-IR spectroscopic tests that the synthesised AgNPs contained functional groups such NH, CH, CH_3, CO, and NH_3^+. Using the Scherrer formula, the average crystallographic size of the nanoparticles determined from XRD is 43.52 nm. AgNPs' surface morphology was nearly rod-shaped in the SEM pictures. Using bio synthesised AgNPs, the antimicrobial activity of gram-positive bacteria *Bacillus subtilis*, Gram-positive *Proteus mirabilis*, and fungi *Rhizopus microsporus* and *Penicillium sp.* was investigated. The findings indicate that as compared to Gram-negative *Proteus mirabilis*, AgNPs exhibits a greater level of inhibition against Gram-positive *B. subtilis*. When compared to *Rhizopus microsporus*, AgNPs were reported to have higher antifungal efficacy against *Penicillium sp*. Comparing the photoactive nanoparticles to other photocatalytic systems, there are several advantages.

References

1. Maryan A. S., Montazer M. and Harifi T. Synthesis of nano silver on cellulosic denim fabric producing yellow colored garment with antibacterial properties. Carbohydrate polymers. 2015; 115, 568 - 574.
2. Mirjalili M., Yaghmaei N. and Mirjalili M. Antibacterial properties of nano silver finish cellulose fabric. Journal of Nanostructure in Chemistry. 2013; 3, 1 - 5.
3. Montazer M., Ali mohammadi F., Shamei A. and Rahimi M. K. Durable antibacterial and cross-linking cotton with colloidal silver nanoparticles and butane tetracarboxylic acid without yellowing. Colloids and Surfaces B: Biointerfaces. 2012; 89, 196 - 202.
4. Kathirvelu S., D'souza L. and Dhurai B. UV protection finishing of textiles using ZnO nanoparticles. 2009
5. Vivek R., Thangam R., Muthuchelian K., Gunasekaran P., Kaveri, K. and Kannan S. Green biosynthesis of silver nano particles from Annona squamosa leaf extract and its invitro cytotoxic effect on MCF-7 cells. Process Biochemistry. 2012; 47(12), 2405 - 2410.
6. Rodríguez-León E. Iniguez-Palomares R., Navarro R.E., Herrera-Urbina, R., Tánori J., Iniguez-Palomares C. and Maldonado A. Synthesis of silver nanoparticles using reducing agents obtained from natural sources (*Rumex hymenose palus* extracts). Nanoscale research letters. 2013; 8, 1 - 9.
7. Sadeghi B., Rostami A. and Momeni S.S. Facile green synthesis of silver nanoparticles using seed aqueous extract of *Pistacia atlantica* and its antibacterial activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2015; 134, 326 - 332.
8. Baazeem A., Almanea A., Manikandan P., Alorabi M., Vijayaraghavan P. and Abdel-Hadi A. In vitro antibacterial, antifungal, nematocidal and growth promoting activities of *Trichoderma hamatum* FB10 and its secondary metabolites. Journal of Fungi. 2021; 7(5), 331.
9. Al-Ansari M.M., Andeejani A.M., Alnahmi E., AlMalki R.H., Masood, A., Vijayaraghavan P., Rahman A.A. and Choi K.C. Insecticidal, antimicrobial and antioxidant activities of essential oil from Lavandula latifolia L. and its deterrent effects on *Euphoria leucographa*. Industrial Crops and Products. 2021; 170, 113740.
10. Vanaja M., Paulkumar K., Baburaja M., Rajeshkumar S., Gnanajobitha G., Malarkodi C.,

Sivakavinesan M. and Annadurai G. Degradation of methylene blue using biologically synthesized silver nanoparticles. Bioinorganic chemistry and applications, 2014.

11. Brucely Y., Shaji Y.C., Paulraj G., Manikandan D., Nagaprasad N., Singh R., Gupta L.R., Tesfaye J.L., Badassa B. and Krishnaraj R. Synthesis and characterization of natural fibre with ZnO nanocomposites. International Journal on Interactive Design and Manufacturing (IJIDeM).2023; 17(5), 2445 - 2452.