Green Synthesis of Silver Nanoparticles Utilizing Withania somnifera: Characterization and Applications

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ABSTRACT
The use of natural materials, particularly plant extracts, to produce silver nanoparticles has gained popularity as an ecologically beneficial and sustainable process known as green synthesis. Plant extracts are preferred over chemical, physical, and microbe-based approaches for biosynthetic processes. This approach is appropriate for nanoscale metal production as it does not require an aseptic environment. Nanotechnology is gaining tremendous impetus in the present century due to its capability of modulating metals into their nanosize, which drastically changes the chemical, physical and optical properties of metals. Withania somnifera, often known as ashwagandha, is a medicinal herb known for its numerous therapeutic benefits. This study investigates the green manufacture, characterization, and potential uses of silver nanoparticles (AgNPs). The green synthesis of WS-AgNPS, which provides a sustainable method of nanoparticle manufacture. The synthesised WS-AgNPs are characterised using a variety of analytical techniques, including UV-Visible spectroscopy, FTIR, XRD and TEM. Furthermore, these WS-AgNP nanoparticles have a variety of biological applications, including antibacterial activity.

Key words: Nano, Green, Ecofriendly, Plant, Biological

1. INTRODUCTION

The goal of green nanotechnology is to make it easier to produce products based on nanotechnology that are safe, healthy, and environmentally benign for all living things while maintaining a sustainable commercial viability

Plants play a crucial role in the production of bio fabricated nanoparticles. Plants create metabolites, which aid in the breakdown of precursor molecules. They function as a catalyst and stabiliser during the production of WS-AgNPs. Withaniasomnifera, often known as Ashwagandha, has been extensively explored for its pharmacological properties and therapeutic potential in traditional medicine frameworks such as Ayurveda. With the growing interest in nanotechnology and nanoparticle manufacturing, the usage of natural resources has become increasingly important due to its environmental friendliness and biological applications. Silver nanoparticles (AgNPs) have gained popularity in recent years due to their biological capabilities as antioxidants, antibacterials, and anticancer agents (1). Integrating the advantages of Withania somnifera with the characteristics of AgNPs gives a feasible approach for developing newinnovative therapeutic agents with better efficacy and lower toxicity.

Nanotechnology is gaining tremendous impetus in the present century due to its capability of modulating metals into their nanosize, which drastically changes the chemical, physical and optical properties of metals. Silver nanoparticles have particular properties that may perhaps have numerous applications in the fields of optics, dentistry, clothing, catalysis, electronics and food industry. [9]

2. MATERIALS &METHODS

Preparation of Plant Extract

The plant extract was obtained by washing the plant with distilled water multiple times and allowing them to dry for 24 hours. Subsequently, the plants were grind by using a standard grinder.The extract was then made by heating& stirring at 40-50^{0}C for 10 minutes. It was filtered and centrifuged for 10-15 minutes. Finally, the supernatant was recovered after filtering.

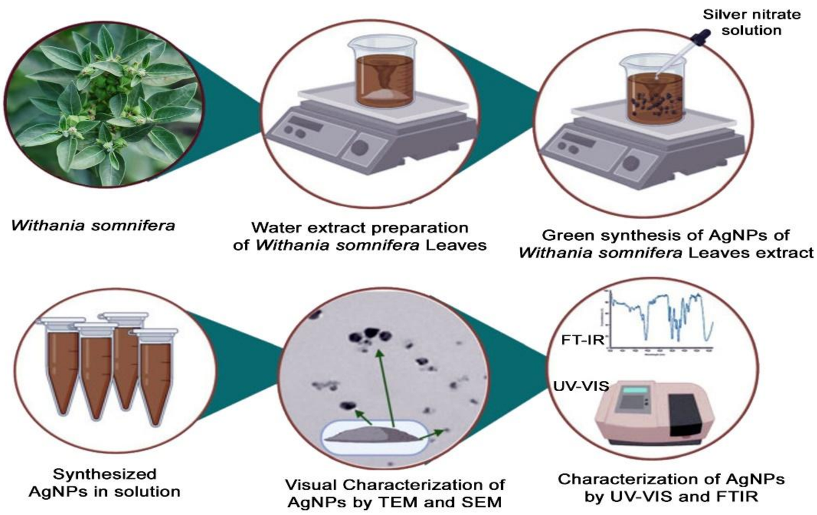

Figure 1. Synthesis& Characterization of WS-AgNPs

Synthesis AgNps

A 1mM silver nitrate solution was produced in doubly distilled water.The solution of silver nitrate and plant extract were combined at a set ratio of 1:9.The reaction mixture was heated and stirred at 800 RPM. After heating and stirring, the mixture became a crimson brown tint.This reaction was carried out in the dark, and the resultant suspension was centrifuged at 15,000 rpm for 40-45 minutes. To eliminate contaminants, the precipitate was washed three to four times with deionized water. The synthesised WS-AgNPs were kept in a cold, dark, and dry environment for the characterisation process[2.]

3. CHARACTERIZATIONS OF NANOPARTICLES

Ftir& Edx Analysis

The FTIR characterization techniques for WS-AgNPs offer a valuable approach to identify the different peaks associated with functional groups found in Withania somnifera silver nanoparticles[3.]The presence of hydroxyl groups (OH) from alcohols or phenol is observed at: 3200-3600 cm^{-1}. C-H Stretchingpeak is observed at 2903 cm^{-1},which indicates the presence of aromatic compounds or alkanes. C=O Stretchingpeak is observedat 1646 cm^{-1},this peak represents carbonyl groups (C=O) from aldehydes, ketones, carboxylic acids, or esters. N-H Bending peak is observed at 1543 cm^{-1},this peak represents the bending vibrations of amine groups. C=C Stretching peak is at 1453 cm^{-1}: due to presence of aromatic rings, implying phenolic compounds from the plant extract. The peak observed at 1314^{-}cmis due to C-O stretching vibrations that can be attributed to alcohols, ethers, carboxylic acids, or esters.C-N Stretchingpeak is observed at 1030 cm^{-1}which indicates the presence of aliphatic amines.C-Xpeak indicatesfor alkyl halide at 800 cm-1

These peaks represent several biomolecules detected in the Withania somnifera extract that contribute to the green production and stabilisation of silver nanoparticles. These biomolecules' functional groups serve as reducing agents, turning silver ions into silver nanoparticles, and capping agents, stabilising the nanoparticles. (4)

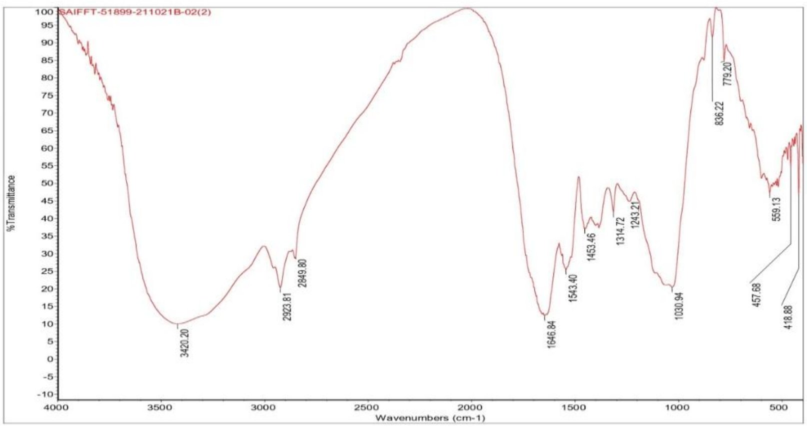

Figure 2. FT IR Spectrum

Energy Dispersive X Ray Analysis

Elemental analysis of Ws-AgNPs using FESEM-EDX reveals the presence of 93% Ag and 5% oxides, as seen in Figure 3. The elemental analysis of WS-AgNPs was validated by EDX, as shown in Fig 3. At 3 KeV, there was a high peak signal indicating metallic silver nanoparticle absorption. The lack of additional components validates the produced nanoparticles' purity.

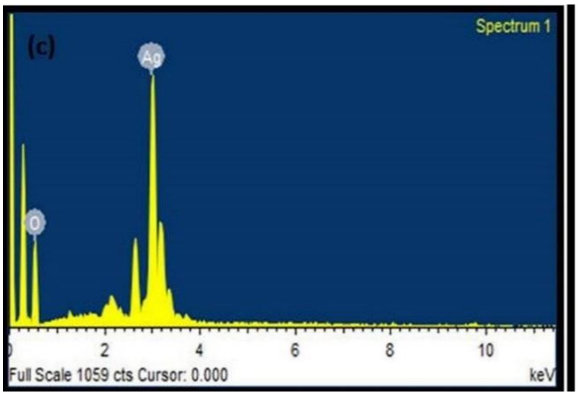

Figure 3. EDX Spectra

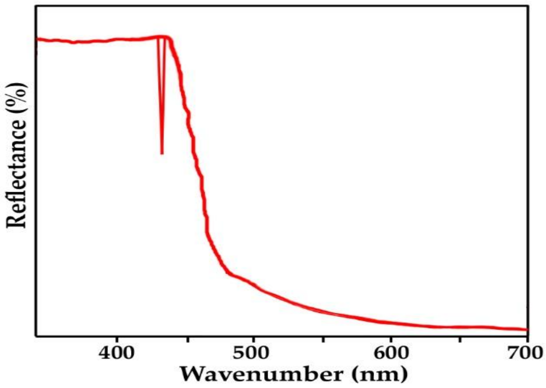

Figure 4. UV-Visible Spectrum

Uv Visible Absorbtion Spectra

UV-Vis spectroscopy was used to analyse the WS-AgNPS. The prominent peaks represent the silver nanoparticles' surface plasmon resonance band. [5]

UV/VIS peaks.

The Surface Plasmon Resonance (SPR) peak occurs between 420 and 450 nm. The SPR band for silver nanoparticles is typically observed in this range. The placement of the peak varies according to the size and form of the Ws-AgNPS. This peak represents the collective oscillation of electrons in reaction to light, indicating the presence of silver nanoparticles.

SEM & TEM Analysis

SEM and TEM are used to determine the size of synthesised silver nanoparticles. However, TEM generates higher-resolution images, allowing for more accurate size measurements. WSAgNPs have a narrow size distribution, with typical sizes ranging from 50 to 75 nm.

XRD Spectra

XRD is used to determine the crystalline structure of the nanoparticles. Important peaks for WS-NPs are typically observed at specific 2θ angles corresponding to the face-centred cubic (fcc) structure of silver:

- **37.3°**: This peak corresponds to the (111) plane of silver.
- **44.3°**: This peak corresponds to the (200) plane of silver.
- **65.5°**: This peak corresponds to the (220) plane of silver.
- **77.5°**: This peak corresponds to the (311) plane of silver.

These peaks confirm the presence of crystalline silver nanoparticles[6]

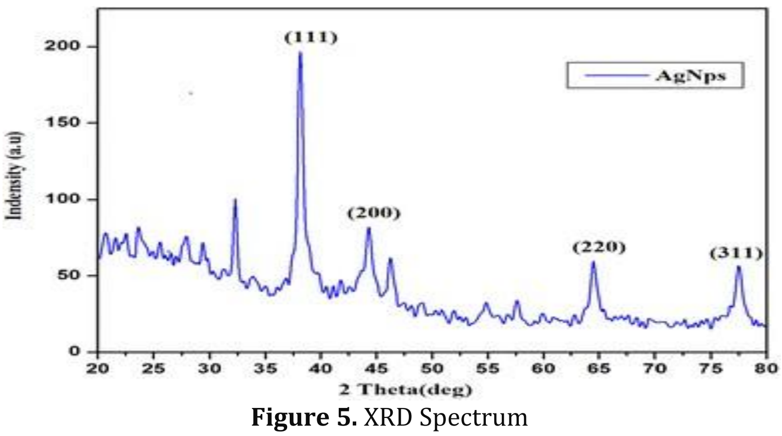

Figure 5. XRD Spectrum

Antibacterial Activities

There are several methods in which silver nanoparticles might cause these effects. According to reports, silver nanoparticles interact with proteins and enzymes' thiol groups, which are crucial for the bacterial respiration as well as the movement of vital materials through the cell membrane and inside the cell. The bacterial cell membrane's function can be changed by silver nanoparticles binding to the bacterial wall and outside bacterial cell.

Zone of Inhibition

In this procedure, AgNPs are inserted into wells on an agar plate infected with bacteria. The zone of inhibition (clear region surrounding the well) that inhibits bacterial growth is used to quantify antibiotic efficacy. Larger zones imply more antibacterial action.[7,8,10:] Efficacy against various bacterial strains.

1. Gram-positive bacteria

o Staphylococcus aureus (WS) AgNPs have significant antibacterial activity against this common Gram-positive bacterium. Gram-positive bacteria have larger but less complex cell walls, which allows for effective interaction with AgNPs.

2. Gram-negative bacteria

Escherichia coli (WS) AgNPs are effective against Gram-negative bacteria, such as E. coli. Although Gram-negative bacteria's outer membrane serves as an additional barrier, AgNPs can penetrate and disrupt membrane integrity.

Silver nanoparticles derived from Withania somnifera extract exhibit significant antibacterial activity against both Gram-positive and Gram-negative bacteria.

Table 1.

Concentration SeNPS(ug/ml)	Zone of inhabitation(mm)	
	Gram Positive S. Aureus	Gram Positive E.Coli
100	11 ± 0.22	11 ± 0.22
150	12 ± 0.20	12± 0.40
200	13 ± 0.68	13± 0.88

Values of a zone of inhibition (mm)

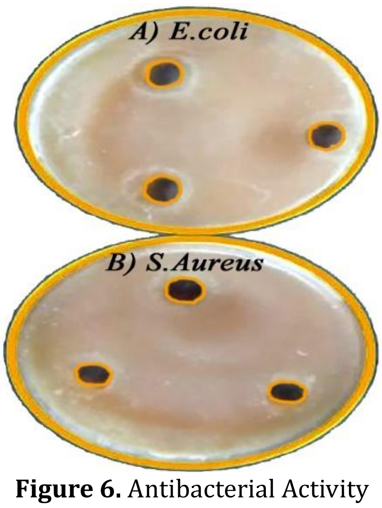

Figure 6. Antibacterial Activity

4. CONCLUSION

A green synthesis of silver nanoparticles based on Withania somnifera extract provides a sustainable and environmentally method of nanoparticle generation. The synthesised WS-AgNPs have antibacterial properties, among other biological applications. Silver nanoparticles derived from Withania somnifera have significant antibacterial activity against both Gram-positive and Gram-negative bacteria. These biogenic ways of synthesising AgNPs are increasingly chosen over conventional chemical and physical procedures since they incorporate living beings such as plants, microalgae, and other microorganisms.Silver nanoparticles synthesized by Withania somnifera showed greater activity then

chemical synthesis.
According to the aforementioned findings, Withania somnifera's silver nanoparticles may have advantageous preventative and therapeutic effects. In-depth research on the mechanism of action, safety, and efficacy must still be done through toxicological experiments, animal studies, and clinical trials before commercially viable medicinal drugs may be developed.

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CONFLICT OF INTEREST
None

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Data Availabilty Statement
The authors confirm that the data supporting the findings of this study are available within the article

Ethics Statement
None

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