



Biosynthesis of Silver–Selenium Nanoparticles Using Sophorin and Their Anticandidal Activities

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Abstract

Introduction

Fungal infections caused by *Candida* species are increasing due to antifungal drug resistance. Green synthesis of nanoparticles using plant-derived compounds has emerged as an eco-friendly approach for developing effective antimicrobial agents. Sophorin-mediated silver–selenium nanoparticles were synthesized and evaluated for their anticandidal activity.

Materials and Methods

Silver–selenium nanoparticles (S-AgSeNPs) were synthesized using silver nitrate, sodium selenite, and sophorin as a reducing and stabilizing agent. The synthesized nanoparticles were characterized using UV–Visible spectroscopy, SEM, EDX, and FTIR analyses. Anticandidal activity was assessed using the agar well diffusion method against *Candida* species.

Results

The formation of S-AgSeNPs was confirmed by color change and UV–Visible spectral analysis. SEM and EDX studies verified the morphology and elemental composition of the nanoparticles, while FTIR confirmed the involvement of functional groups in stabilization. The nanoparticles showed strong antifungal activity with a zone of inhibition of 35 mm against *Candida* species.

Discussion

The study demonstrated that sophorin effectively facilitated the green synthesis of stable silver–selenium nanoparticles. The synthesized nanoparticles exhibited enhanced anticandidal activity due to the synergistic antimicrobial effects of silver and selenium. Their nanoscale size and bioactive surface properties may contribute to effective fungal cell inhibition.

Conclusion

Sophorin-mediated silver–selenium nanoparticles were successfully synthesized using an eco-friendly method and showed potent anticandidal activity. These nanoparticles may serve as promising alternatives for the development of novel antifungal therapeutics.



Introduction

Nanotechnology has emerged as one of the most rapidly advancing fields in biomedical science due to its wide applications in drug delivery, diagnostics, antimicrobial therapy, and tissue engineering.(1) Among various nanomaterials, metallic nanoparticles have attracted considerable attention because of their unique physicochemical and biological properties.(2) Silver nanoparticles are especially recognized for their broad-spectrum antimicrobial activities, whereas selenium nanoparticles are known for their antioxidant, anticancer, and antimicrobial properties. The combination of silver and selenium into bimetallic nanoparticles offers synergistic biological activities with enhanced therapeutic potential.(3)

Conventional methods for nanoparticle synthesis often involve hazardous chemicals, high energy consumption, and toxic by-products, which may limit their biomedical applications.(4) Consequently, green synthesis approaches using plant-derived biomolecules have become increasingly popular due to their eco-friendly, cost-effective, and sustainable nature. Phytochemicals such as flavonoids, polyphenols, alkaloids, and glycosides can function as reducing and stabilizing agents during nanoparticle synthesis.(5)

Sophorin is a naturally occurring flavonoid glycoside possessing several biological properties, including antioxidant and antimicrobial activities.(5) Due to the presence of hydroxyl and carbonyl functional groups, sophorin can effectively participate in the reduction of metal ions and stabilization of synthesized nanoparticles. The utilization of sophorin in nanoparticle synthesis represents an environmentally benign strategy for producing biologically active nanomaterials.(5) Fungal infections caused by *Candida* species represent a major global health concern, particularly among immunocompromised individuals.(6) The increasing resistance of *Candida* species to conventional antifungal drugs such as fluconazole necessitates the development of alternative antifungal agents. Nanoparticles synthesized through green methods have demonstrated promising antifungal activities owing to their small size, large surface area, and ability to disrupt fungal cell membranes.(7)

Therefore, the present study aims to synthesize silver–selenium nanoparticles using sophorin and investigate their anticandidal activity. The synthesized nanoparticles were characterized using UV–Visible spectroscopy, SEM, EDX, and FTIR analyses, followed by evaluation of their antifungal efficacy against *Candida* species.(8)

Materials and Methods

Materials

Silver nitrate (AgNO_3), sodium selenite (Na_2SeO_3), sophorin, and other analytical-grade reagents were used in the study. Distilled water was employed throughout the experiments. Fluconazole was used as the standard antifungal drug for comparative analysis.

Preparation of Sophorin-Mediated Silver–Selenium Nanoparticles

Silver–selenium nanoparticles were synthesized using a green synthesis approach. Silver nitrate and sodium selenite solutions were prepared separately in distilled water. Sophorin solution was



then added to the precursor mixture under continuous stirring. The reaction mixture was incubated until a visible color change occurred, indicating the formation of nanoparticles. The synthesized nanoparticles were collected by centrifugation, washed repeatedly with distilled water to remove impurities, and dried for further characterization.

The synthesis process involved:

1. Silver nitrate solution
2. Sodium selenite solution
3. Sophorin extract
4. Formation of S-AgSeNPs

The color transition confirmed nanoparticle formation.

UV–Visible Spectroscopy

The optical properties of the synthesized nanoparticles were analyzed using UV–Visible spectroscopy. The absorbance spectrum was recorded within the wavelength range suitable for nanoparticle characterization. The appearance of characteristic surface plasmon resonance peaks confirmed nanoparticle formation.

Scanning Electron Microscopy (SEM)

The morphology and surface characteristics of the synthesized S-AgSeNPs were examined using Scanning Electron Microscopy. Dried nanoparticle samples were mounted on conductive stubs and coated appropriately before imaging.

Energy Dispersive X-ray Spectroscopy (EDX)

EDX analysis was performed along with SEM to determine the elemental composition of the synthesized nanoparticles. The presence of silver and selenium peaks confirmed successful nanoparticle synthesis.

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR analysis was conducted to identify the functional groups involved in nanoparticle synthesis and stabilization. Spectra of sophorin and synthesized S-AgSeNPs were compared to evaluate the interaction between biomolecules and nanoparticles.

Anticandidal Activity

The antifungal activity of the synthesized nanoparticles was evaluated against *Candida* species using the agar well diffusion method. Sterile agar plates inoculated with fungal cultures were prepared, and wells were loaded with nanoparticle samples. Fluconazole served as the standard antifungal control. After incubation, the zone of inhibition (ZOI) was measured in millimeters.

Results

Synthesis of Silver–Selenium Nanoparticles



The synthesis of S-AgSeNPs was confirmed by a visible color change in the reaction mixture after the addition of sophorin to silver nitrate and sodium selenite solutions. The observed color transformation indicated the reduction of metal ions and formation of nanoparticles.

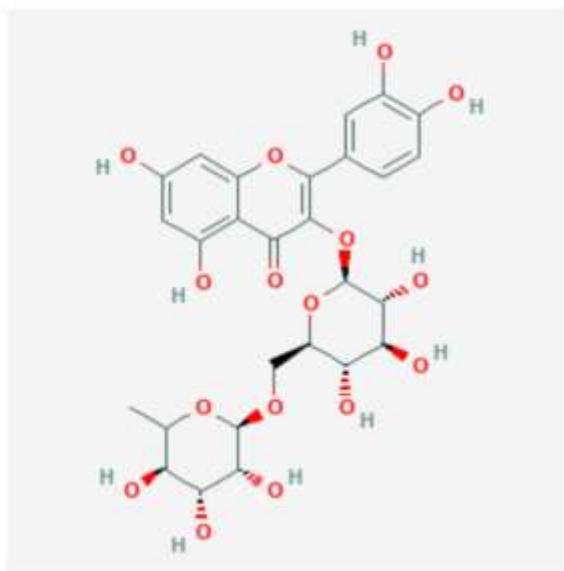


Fig. 1. Structure of sophorin

UV–Visible Spectroscopy Analysis

UV–Visible spectroscopy analysis confirmed the formation of silver–selenium nanoparticles through characteristic absorption peaks associated with nanoparticle surface plasmon resonance. The spectrum demonstrated successful nanoparticle synthesis and stability.

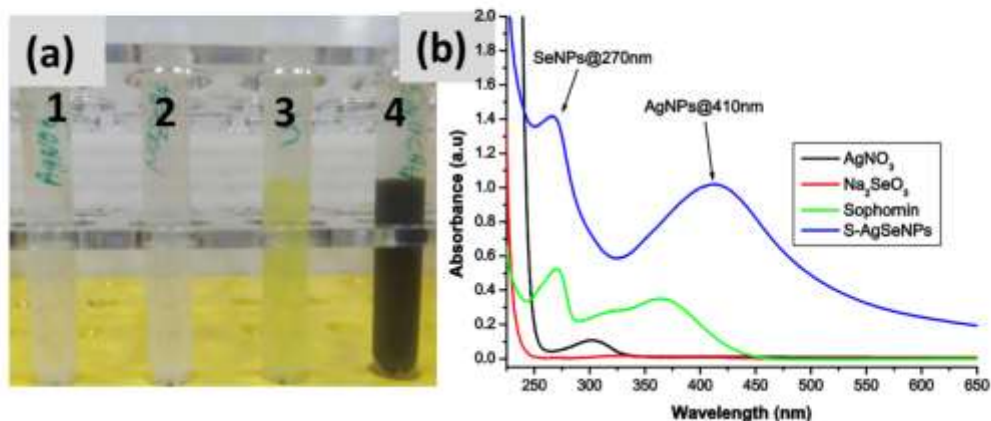


Fig. 2. (a) Synthesis and (b) UV-vis analysis of S-AgSeNPs.
(1 Silver nitrate (AgNO_3), 2 Sodium selenite (Na_2SeO_3), 3 Sophorin, 4 S-AgSeNPs)

SEM Analysis

SEM images revealed that the synthesized nanoparticles possessed nanoscale dimensions with relatively uniform morphology. The particles appeared aggregated in certain regions, which may be attributed to intermolecular interactions among nanoparticles during the drying process. The nanosized morphology contributes significantly to their biological activity due to increased surface area.

EDX Analysis

EDX analysis confirmed the elemental composition of the synthesized nanoparticles. Distinct peaks corresponding to silver and selenium verified the successful synthesis of silver–selenium nanoparticles. The presence of these elements indicated effective reduction and incorporation into the nanoparticle structure.

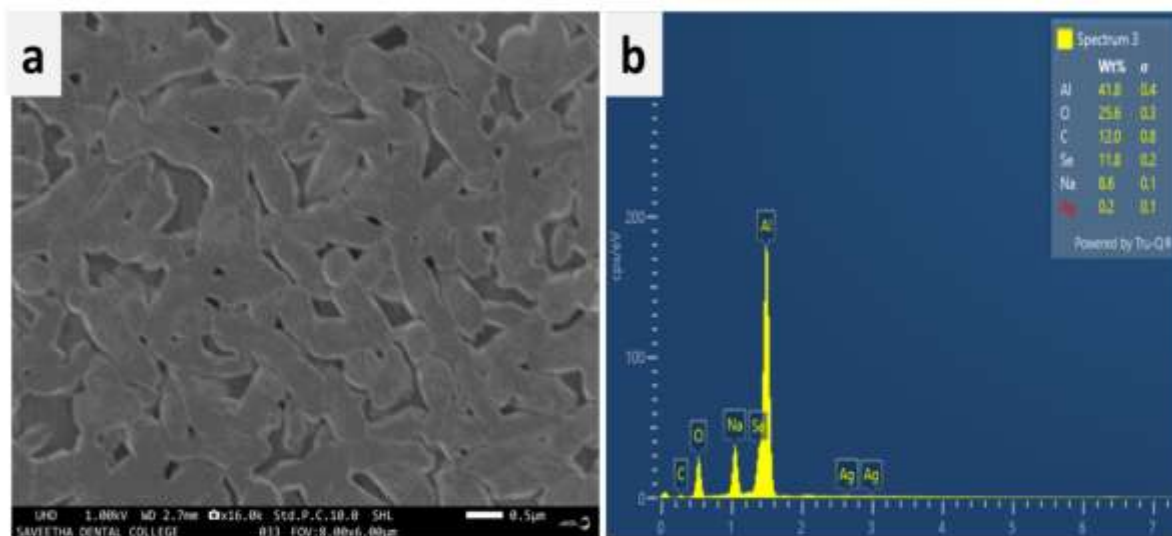


Fig. 3. (a) SEM image and (b) EDX micrograph of S-AgSeNPs.

FTIR Analysis

FTIR spectra demonstrated the presence of important functional groups involved in nanoparticle synthesis and stabilization. The observed hydroxyl (OH) and carbonyl (C=O) groups suggested that sophorin acted as both a reducing and capping agent during nanoparticle formation.

Variations between the spectra of pure sophorin and S-AgSeNPs confirmed interactions between biomolecules and nanoparticles.

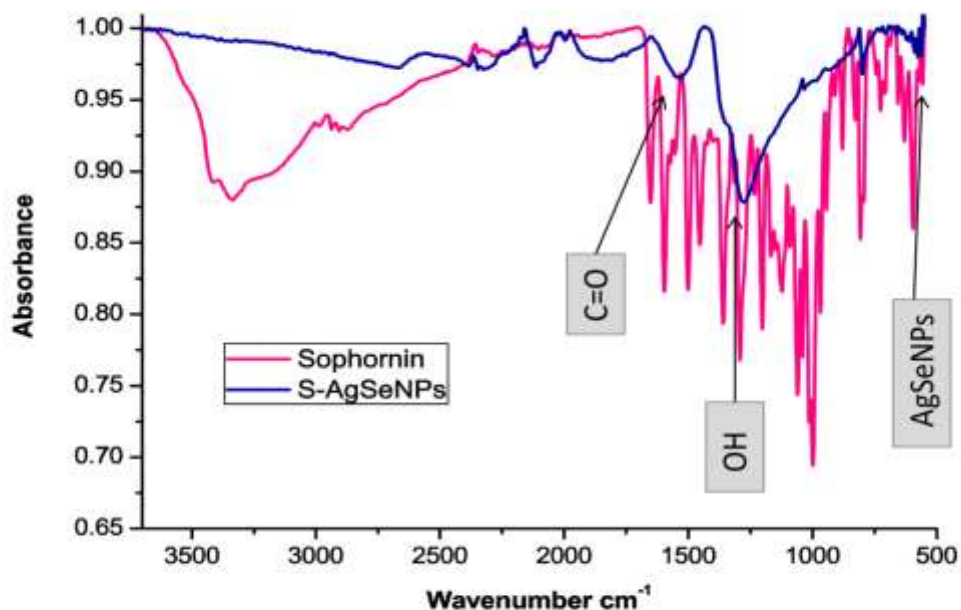


Fig. 4. FTIR spectra of sophorin and S-AgSeNPs.

Anticandidal Activity

The synthesized S-AgSeNPs exhibited remarkable antifungal activity against *Candida* species. The nanoparticles produced a significant zone of inhibition measuring 35 mm, indicating strong anticandidal efficacy. The antifungal effect was comparable to or greater than the standard antifungal drug fluconazole.

Comparative analysis demonstrated enhanced antifungal performance of S-AgSeNPs, suggesting their potential application as alternative antifungal agents.



Fig. 5. Antifungal activity of S-AgSeNPs against *Candida*.

Zone of inhibition (ZOI) study / S – Sophorin

Ab – Antibiotic (Fluconazole)

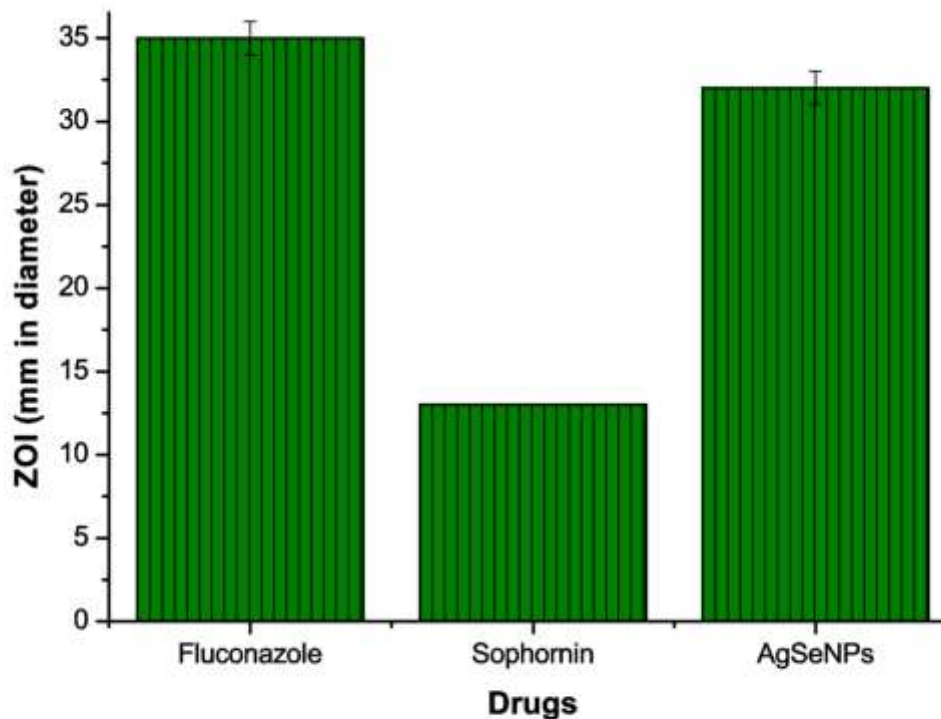


Fig. 6. Comparative analysis of S-AgSeNPs antifungal efficacy.

Discussion

The present study successfully demonstrated the green synthesis of silver–selenium nanoparticles using sophorin as a reducing and stabilizing agent. The environmentally friendly synthesis approach eliminates the need for toxic chemicals and provides a sustainable alternative for nanoparticle production.(9)

The observed color change during synthesis indicated the reduction of silver and selenium ions into nanoscale particles. UV–Visible spectroscopy further confirmed nanoparticle formation through characteristic absorption peaks, which are commonly associated with surface plasmon resonance phenomena in metallic nanoparticles.(10)

SEM analysis revealed nanosized particles with relatively uniform morphology. Nanoparticle size and morphology play essential roles in determining biological activity, as smaller particles possess larger surface areas that facilitate interaction with microbial cells. The EDX spectrum confirmed the successful incorporation of silver and selenium into the synthesized nanoparticles.(11)

FTIR analysis indicated that hydroxyl and carbonyl groups present in sophorin were actively involved in the reduction and stabilization processes. These phytochemical constituents likely contributed to nanoparticle stability by preventing aggregation and enhancing biological compatibility.(12)



The synthesized S-AgSeNPs exhibited strong anticandidal activity against *Candida* species, with a zone of inhibition measuring 35 mm. The enhanced antifungal activity may be attributed to multiple mechanisms, including disruption of fungal cell membranes, generation of reactive oxygen species, interference with cellular metabolism, and damage to intracellular components.(3)(6)

Silver ions are known to interact with sulfur-containing proteins and nucleic acids, leading to cellular dysfunction, whereas selenium contributes additional antimicrobial and oxidative stress-inducing properties. The synergistic interaction between silver and selenium may therefore explain the potent antifungal activity observed in this study.

The findings of this work are consistent with previous reports demonstrating the antimicrobial efficacy of green-synthesized metallic nanoparticles. However, the use of sophorin-mediated silver–selenium nanoparticles provides a novel and promising approach for developing effective antifungal nanotherapeutics.(10)

Further studies involving cytotoxicity evaluation, mechanism of action analysis, and in vivo antifungal assessment are necessary before clinical application.

Conclusion

The present study successfully synthesized silver–selenium nanoparticles using sophorin through a simple and eco-friendly green synthesis method. Characterization studies including UV–Visible spectroscopy, SEM, EDX, and FTIR confirmed the successful formation, morphology, elemental composition, and functional group interactions of the synthesized nanoparticles.

The synthesized S-AgSeNPs demonstrated significant anticandidal activity against *Candida* species, producing a zone of inhibition of 35 mm. The strong antifungal activity suggests that these nanoparticles possess promising biomedical potential as alternative antifungal agents.

Overall, sophorin-mediated silver–selenium nanoparticles represent an effective, sustainable, and biologically active nanomaterial with potential applications in antimicrobial therapy and pharmaceutical research.

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