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Biosynthesis of Silver Nanoparticles Using *Ficus benjamina* Aqueous Leaf Extract and their Antimicrobial Activity

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Abstract

Silver nanoparticles (AgNPs) are widely recognized for their unique physicochemical properties and potent antimicrobial activity. However, traditional chemical synthesis methods often involve toxic reagents and energy-intensive processes. Green synthesis offers a safer and environmentally friendly alternative by using plant-based materials. Ficus benjamina (weeping fig), rich in phytochemicals like flavonoids and alkaloids, presents a promising option for the biosynthesis of due to its known medicinal and antimicrobial properties. Bio-synthesized Ag nanoparticles using Ficus benjamina leaves were characterized using UV–Visible spectroscopy over a 48-hour period. Antimicrobial efficacy was tested against Staphylococcus aureus, Escherichia coli, and Mucor spp using the disc diffusion method, and inhibition zones were compared with standard drugs (ciprofloxacin and ketoconazole). The UV–Vis spectral analysis confirmed the synthesis of AgNPs with a maximum absorbance at 395 nm, consistent with values reported in previous literature. The synthesized AgNPs exhibited concentration-dependent antimicrobial activity, with inhibition zones decreasing from 100% to 25% AgNP concentrations. While the AgNPs were less effective than standard antibiotics, they still demonstrated significant inhibition, particularly against S. aureus (20mm – 27). The results were consistent with related studies reporting similar antimicrobial trends. This study confirms the successful green synthesis of AgNPs using Ficus benjamina extract, offering an eco-friendly route to producing nanoparticles with antimicrobial properties. Though not as effective as conventional drugs, the biosynthesized AgNPs show promising potential as alternative antimicrobial agents when optimized.

Keywords: Green synthesis, Silver nanoparticles, *Ficus benjamina*, Antimicrobial activity, UV–Vis spectroscopy.

Introduction

Over the past decade, the synthesis of nanomaterials, including metal nanoparticles, quantum dots, carbon nanotubes, and graphene, has become a significant focus in nanoscience and technology [1,2]. Nanotechnology, working within the 1–100 nm scale, has brought revolutionary applications across fields like bioengineering, dentistry, and pharmaceuticals due to the unique properties of nanoparticles such as high surface area to volume ratio, distinct color, and thermal, chemical, and optical stability [3,4,5]. Among these, silver nanoparticles (AgNPs) are of particular interest due to their broad-spectrum antimicrobial properties and biocompatibility [3,6].

Traditional physical and chemical synthesis methods for nanoparticles often involve toxic substances and high energy demands. As a safer alternative, green synthesis has gained popularity by using plant extracts and microorganisms as reducing and stabilizing agents, making the process eco-friendly, cost-effective, and non-toxic [7,8,6]. This biological approach benefits from plant-derived phytochemicals such as flavonoids, phenols, terpenoids, and alkaloids, which enable the reduction of metal ions and the capping of nanoparticles [9,10].

One notable plant used in green synthesis is *Ficus benjamina* (weeping fig), a tropical species from the Moraceae family. It contains a wide range of bioactive compounds including phenolics, flavonoids, alkaloids, and saponins, contributing to its recognized medicinal potential [11,12].

Traditionally, *Ficus benjamina* has been employed to treat infections, intestinal issues, and inflammatory conditions, and exhibits antimicrobial, antipyretic, and analgesic properties [13]. Furthermore, silver nanoparticles synthesized using plant extracts exhibit remarkable antibacterial efficacy against both Gram-positive and Gram-negative bacteria by disrupting cellular functions, damaging DNA, and generating reactive oxygen species [14,3]. Due to these advantages, green-synthesized AgNPs have found wide applications in medicine, textiles, food packaging, and environmental remediation [15,16].

Therefore, this study aimed to study the biosynthesis of silver nanoparticles using *Ficus benjamina* aqueous leaf extract and their antimicrobial activity. The green synthesis of AgNPs using *Ficus benjamina* could offer a sustainable and promising approach for producing antimicrobial agents with minimal environmental impact.

Materials and Methods

Preparation of 1 mM Silver Nitrate ($AgNO_3$) Solution

A calculated mass of silver nitrate ($AgNO_3$) was determined using the formula:

Number of moles = Mass / Molar mass

The required mass of $AgNO_3$ was accurately weighed and transferred into a clean 500 mL standard volumetric flask. Deionized water was added, and the solution was thoroughly mixed by shaking. The solution was then diluted to the mark with additional deionized water.

Preparation of Plant Extracts

Fresh leaves of *Ficus benjamina* were collected, thoroughly washed with deionized water, and oven-dried at 40 °C for 24 hours. The dried leaves were then ground into a fine powder. From the powdered plant sample, 1.5 g was weighed and boiled in 100 mL of deionized water. The resulting solutions were filtered using Whatman No. 1 filter paper. The filtered extracts were stored for subsequent use.

Biosynthesis of Silver Nanoparticles

To synthesize silver nanoparticles, 2.5 mL of ammonium solution was added to 5 mL of the previously prepared 1 mM $AgNO_3$ solution in a 100 mL beaker. Subsequently, 10 mL of the prepared plant extract was added to the mixture. The total volume of the solution was adjusted to 50 mL using deionized water. The beaker was kept at room temperature, and a visible colour change from light brown to dark brown indicated the formation of silver nanoparticles due to the reduction of silver ions [16].

Characterization of Silver Nanoparticles

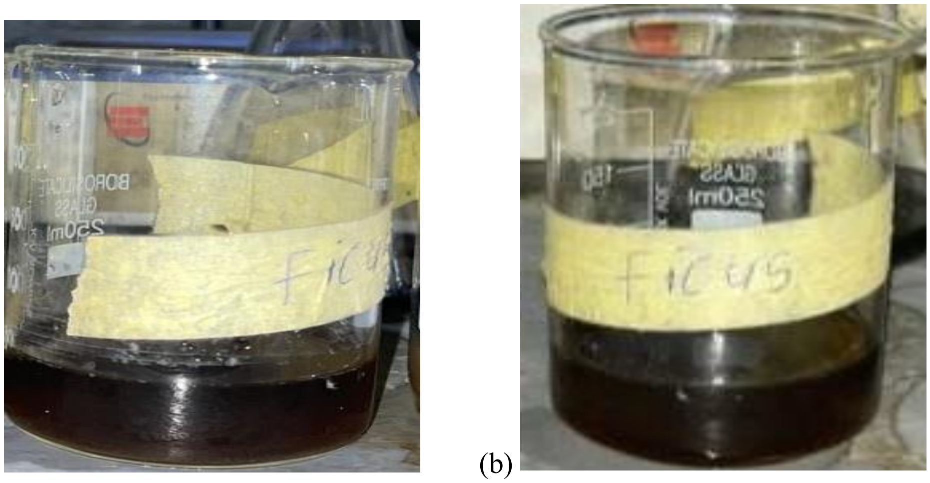
UV-visible spectroscopy (6705 UV/Vis. Spectrophotometer JENWAY, United Kingdom) was employed to analyze the synthesized silver nanoparticles. UV scans were conducted at different time intervals: after 1 hour, 24 hours, and 48 hours post-synthesis. Additionally, UV scans were also performed on both the pure plant extract and the prepared $AgNO_3$ solution to compare the absorption characteristics.

Result and Discussion

Results

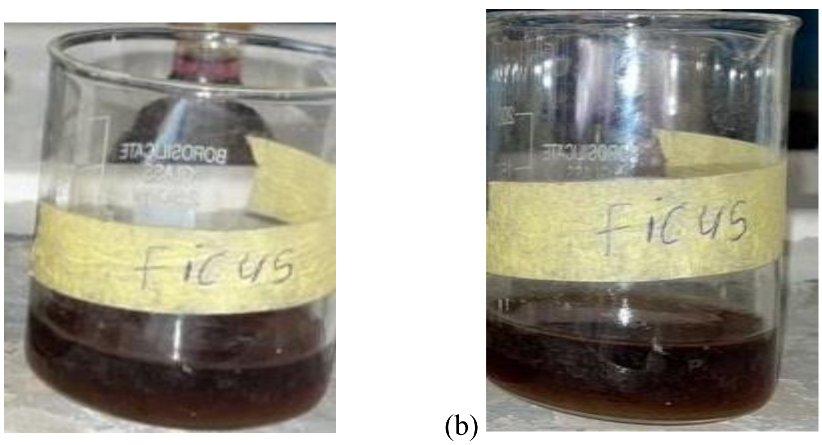
Visible Observation

The gradual color change of reaction mixture ($AgNO_3$ solution and the plant extracts) to black, brown and darker brown indicated the formation of silver nanoparticles as shown in Fig. 1. This color change was due to the surface plasmon vibration, an optical property which is unique to the noble metals (Rautela *et al.*, 2019).



(a) (b)

Figure 1: The Plant Extracts (a) before Synthesis (b) Immediately after Synthesis of *Ficus benjamina*



(a) (b)

Figure 2: The Plant Extracts (a) 24 h After Synthesis (b) 48 h After Synthesis of *Ficus benjamina*

Characterization of Synthesized Silver Nanoparticles

UV–Vis spectroscopy

Table 1: UV-Vis Absorption Spectra of Synthesized AgNPs Compared with Literature Values

Characterization	This Study	Razavi *et al.,* (2021)	Giri *et al.,* (2022);	Al- Nemrawi *et al.,* (2022)	Ibrahim *et al.,* (2024)
UV-Visible Maximum Absorbance (nm)		395	417	396	423

(a) **(b)**

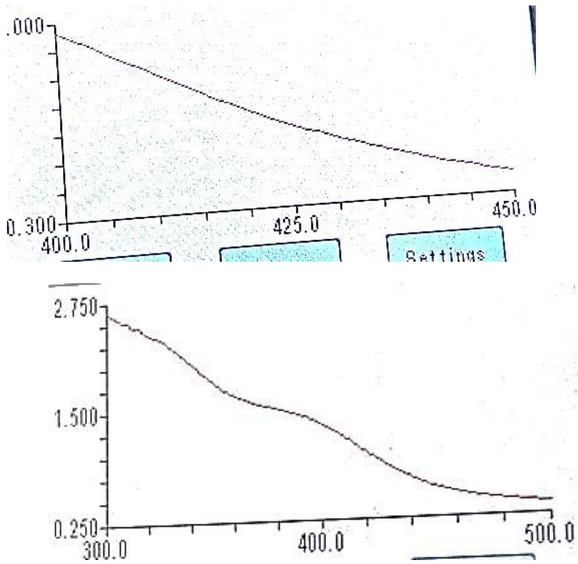


Figure 3: UV-Vis Spectra of (a) Leaf Extract (b) Synthesized AgNPs *Ficus benjamina*

Antimicrobial Activity

Table 2: Antimicrobial Activity of Synthesized AgNPs

Width of Inhibition Zone (mm) of AgNP-*F. benjamina*					
Microorganism (%)	100	75	50	25	C
Staphylococcus aureus	20	18	14	10	27
Escherichia coli	14	11	9	7	21
Mucor spp	12	10	7	5	24

Key: C_{Fungi} = ketoconazole, $C_{Bacteria}$ = ciprofloxacin

Figure 4: Photographic Pictures of Antimicrobial Activity of AgNP-*F. benjamina* (From Right to Left): on *Mucor* spp, *Staphylococcus aureus* and *Escherichia coli* in Petri dishes Culture.

Discussion

The maximum absorbance wavelengths obtained in this study for the extract of *Ficus benjamina* is presented in (Figure 3). The results obtained were similar to Giri *et al.*, (2022); Rautela *et al.*, (2019) obtained a highest peak at 417 nm and 440 nm for the absorbance of *Eugenia roxburghii*-AgNPs and AgNPs-*Tectona grandis* (teak) solutions respectively. Ibrahim *et al.*, (2024) reported the maximum absorbance peak in the absorption spectra of AgNPs synthesized using *acacia raddiana* extract at 423 nm. Jain *et al.* (2014) obtained the maximum absorbance at 200 nm for *Ficus benjamina,* and 425 nm for Neem, tea and onion synthesized AgNPs. The maximum absorption spectrum of synthesized Ag-NPs using *Ficus cordata* extract was obtained at 460 nm (Marzuk *et al.,* 2019). Al-Nemrawi *et al.,* (2022) obtained maximum absorption at 396 nm for the AgNPs synthesized using *bellevalia flexuosa* at pH11, while at pH 12, Razavi *et al.* (2021) obtained the absorption peak at 395 nm for AgNP synthesized using *Artemisia herba- alba* extract. It was reported that the typical absorption spectrum of spherical silver nanoparticles presents a maximum between 420 nm and 450 nm (Al-Nemrawi *et al.,* 2022; Rautela *et al.*, 2019; Bharathi *et al*., 2017; Bahuguna *et al.* 2016).

The results demonstrate that synthesized Ag-NPs exhibited concentration-dependent antimicrobial activity against *S. aureus*, *E. coli*, and *Mucor spp*, with inhibition zones decreasing from 100% to 25% concentrations. Although the inhibition was significant, it remained lower than that of the standard drugs (ciprofloxacin and ketoconazole), indicating Ag-NPs' moderate yet promising efficacy. These findings align with previous studies, such as Singh *et al*. (2021), which reported enhanced antimicrobial effects of Ag-NPs due to their ability to disrupt microbial cell walls and induce oxidative stress. Similarly, Aljabali et al. (2020) observed comparable dose-dependent inhibition against similar pathogens. Thus, while Ag-NPs show potential as alternative antimicrobials, their efficacy may be enhanced through combination therapies or surface modifications.

The Table 2 shows that synthesized silver nanoparticles (AgNPs) from *Ficus benjamina* exhibit dose-dependent antimicrobial activity. As AgNP concentration decreases from 100% to 25%, the inhibition zones reduce across all tested microorganisms, indicating reduced efficacy. *Staphylococcus aureus* showed the highest sensitivity among bacteria, while *Mucor spp.* was the least sensitive overall. However, the standard drugs (ciprofloxacin and ketoconazole) demonstrated superior activity compared to AgNPs. This suggests that while AgNPs possess antimicrobial properties, their effectiveness is lower than conventional antibiotics or antifungals.

The results obtained in this study are similar to the values reported by Garibo *et al.,* (2020), 18.0 ± 1.3 mm for *E. coli*, 16.0 ± 1.0 mm for *S. aureus* and 15.0 ± 0.5 mm for *P. aeruginosa*. Also similar to the results of this study, Sougandhi and Ramanaiah (2020) reported the antibacterial activity of AgNPs synthesized using *Psidium guajava* leaf extract against E. coli as (18.0 ± 1.60 mm), *K. pneumonia* (17.0 ± 0.82 mm), *Bacillus subtilis* (16 ± 1.4 mm), *Pseudomonas auerginosa* (14 ± 1.2 mm) and *S. aureus* (11.0 ± 1.63 mm). Zafar *et al.,* (2018) reported the highest growth inhibition effect of Ag NPs synthesized using *Ficus benjamina* extract of 12 mm against *Bacillus subtilis* and 13 mm against *Enterobacter aerogenes, Staphylococcus aureus* and *Pasteurella multocida* at concentration of 200 µl.

Conclusion

The study successfully demonstrated the green synthesis of silver nanoparticles using *Ficus benjamina* leaf extract, confirmed by visible color changes and UV-Vis spectroscopy. The synthesized AgNPs showed dose-dependent antimicrobial activity, with higher concentrations at 100% yielding greater zones of inhibition against *Staphylococcus aureus* (20 mm), *Escherichia coli* (14 mm) and *Mucor spp* (12 mm). although their activity was lower than that of standard antibiotics used as control having higher inhibition tones against *S. aureus* (27 mm), *E. coli* (21 mm) and *Mucor spp* (24 mm).

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