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Fabrication, Optimization And Characterization Of Silver Nanopartices Using Methanolic Leaf Of Claytonia Perfoliata (R.) Nees For Treating Bacterial Infections

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Abstract
The ethnomedicinal and phytochemical-rich Claytonia perfoliata (R.) Nees methanolic leaf extract is used to greenly synthesise, optimise, and characterise silver nanoparticles (AgNPs). Methanolic extract was used to reduce and stabilise AgNPs, making biosynthesis an eco-friendly and cost-effective alternative to chemical synthesis. To maximise nanoparticle yield and stability, silver nitrate concentration, pH, temperature, and reaction time were optimised. UV–Vis spectroscopy and SEM examination verified AgNP production and shape. Functional groups responsible for reduction and stabilisation were identified. SEM showed crystalline and spherical nanoparticles. The synthesised AgNPs inhibited a panel of harmful microorganisms, particularly Staphylococcus aureus and Escherichia coli. These findings imply that C. perfoliata methanolic leaf extract can be utilised to greenly synthesize AgNPs with promising bacterial infection treatments, paving the path for plant-based nanotherapeutics.
Key-words: *Silver Nanoparticles, Plant Extract,* Claytonia perfoliata

INTRODUCTION

Silver nanoparticles (AgNPs), which are 1 to 100 nanometres in size, have unique physical, chemical, and biological properties. AgNPs are popular in biomedical, pharmacological, and environmental applications due to their high surface area-to-volume ratio and powerful antibacterial action. They are efficient against many pathogenic germs, including drug-resistant forms, because to their potent antibacterial, antifungal, and antiviral activities. AgNPs are also anti-inflammatory, antioxidant, and wound-healing, making them useful in medical devices, medication delivery systems, and topicals. Synthesis can be done physically, chemically, or biologically, however green synthesis utilising plant extracts is preferred due to its eco-friendliness and biocompatibility. Research into silver nanoparticles' safe and effective usage in nanotechnology and medicine continues due to their versatility. [1]

Plant-derived silver nanoparticles (AgNPs) are needed because there is an increasing demand for eco-friendly, cost-effective, and sustainable alternatives to chemical and physical nanoparticle manufacturing. Traditional technologies use toxic reagents, significant energy consumption, and harmful byproducts, creating environmental and health hazards. Plant-mediated synthesis uses natural phytochemicals including flavonoids, terpenoids, alkaloids, and phenolics as reducing and stabilising agents, making it greener. This simplifies synthesis and improves nanoparticle biocompatibility and medicinal potential. Biosynthesised

AgNPs have improved antibacterial, anti-inflammatory, and antioxidant capabilities, making them ideal for biomedical applications, especially against multidrug-resistant bacterial infections. Thus, using plant extracts for AgNP production is green chemistry and promising for producing safe and effective nanomedicines. [2]
Claytonia perfoliata (R.) Nees, known as miner's lettuce, is a fast-growing herbaceous annual native to North America and now naturalised worldwide. The Montiaceae family's leafy vegetable is eaten for its vitamins, minerals, and antioxidants. Its round, perfoliate leaves around the stem make it easy to identify. Claytonia perfoliata has been studied for its ethnomedicinal effects and phytochemical profile, which includes flavonoids, phenolics, and other bioactive components. These elements may have antioxidant, anti-inflammatory, and antibacterial properties. [3] Due to its phytochemicals, the plant is a viable candidate for green nanoparticle synthesis, notably silver nanoparticles for infection control and wound healing.

MATERIAL AND METHODS

Plant Material Collection and Preparation

Claytonia perfoliata leaves were gathered, cleaned with distilled water to eliminate dust, and shade-dried at room temperature. For future usage, dried leaves were mechanically ground and stored in an airtight container. Botanist authenticated plant material and assigned voucher specimen.

Methanolic Leaf Extract

Soxhlet extraction in methanol for 6–8 hours was performed on 250 g of powdered leaf material. A rotary evaporator condensed the extract under reduced pressure after filtering with Whatman No. 1 paper. The concentrated extract was kept at 4°C until usage. [4]

Green Silver Nanoparticle Synthesis

Prepared 1 mM aqueous silver nitrate ($AgNO_3$) solution for AgNP synthesis. The $AgNO_3$ solution was continuously stirred at room temperature while adding a precise volume of methanolic extract dropwise. The reaction mixture was dark-incubated to avoid photoreduction. A pale yellow to brown colour change indicated silver nanoparticle production. [5]

Synthesis Parameter Optimization

To optimise nanoparticle formation, parameters such as $AgNO_3$ concentration (0.5 mM, 1 mM, 2 mM), plant extract volume ratio, reaction medium pH (4-10), temperature (room to 80°C), and reaction duration (0-24 hours) were changed. To identify optimal synthesis conditions, UV–Visible spectrophotometry measured colour change intensity and timing. [6]

Assessment of Antibacterial Activity

The synthesised AgNPs were evaluated for antibacterial activity against harmful bacteria such Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa using agar well diffusion. To test effectiveness, zones of inhibition were determined and compared to standard antibiotics and plant extract controls. [7]

RESULTS AND DISCUSSION

Silver nanoparticles (AgNPs) were greenly synthesised from Claytonia perfoliata (R.) Nees' methanolic leaf extract, optimised, characterised, and tested for antibacterial activity in this study. The synthesis of AgNPs was validated by the steady colour shift of the reaction mixture from pale yellow to dark brown, suggesting the reduction of Ag^+ ions to metallic silver. UV–Visible spectroscopy exhibited a sharp absorption peak around 420–430 nm, typical of AgNPs, confirming surface plasmon resonance caused this colour transition. Optimisation tests found that a 1 mM $AgNO_3$ concentration, 1:2 extract-to-silver nitrate ratio, pH 8, and 60°C temperature resulted in maximal nanoparticle production in 3 hours. Bioactive chemicals in the extract acted as reducing and capping agents, enabling fast nanoparticle nucleation and stabilisation. Major functional groups including hydroxyl, carbonyl, and amine groups were found in FTIR analysis, indicating flavonoids, phenolics, and proteins reduce and stabilise. SEM showed that the synthesised nanoparticles were

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mostly spherical and 20–50 nm in size. Biosynthesised AgNPs were effective against Gram-positive (Staphylococcus aureus) and Gram-negative (Escherichia coli, Pseudomonas aeruginosa) pathogens. The zone of inhibition for AgNPs was substantially higher than the crude plant extract, indicating improved antibacterial effectiveness. AgNPs interact with bacterial cell walls, damage membrane integrity, create reactive oxygen species (ROS), and inhibit DNA replication and protein synthesis due to their tiny size and huge surface area.

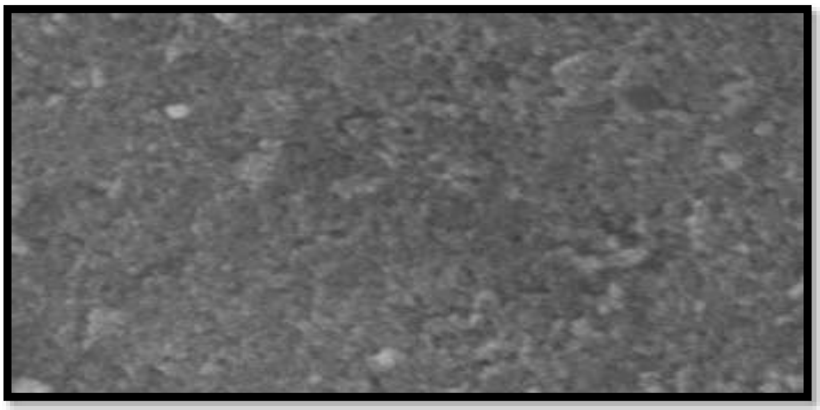

Fig. 1: SEM of Optimized AgNPs

Table 1: Zone of Inhibition of Formulated Silver Nanoparticles

Treatment	**Zone of Inhibition (mm)**		
	Staphylococcus aureus	***Escherichia coli***	***Pseudomonas aeruginosa***
Silver nitrate solution	9.9±0.22	12.86±0.17	11.29±0.22
Commercial antibiotic disc	10.8±0.16	13.39±0.32	10.18±0.06
Formulated AgNPs	14.32±0.15	16.19±0.04	14.27±0.39

The study shows that *Claytonia perfoliata* methanolic leaf extract contains phytochemicals that can help make AgNPs eco-friendly. Optimised synthesis parameters boost nanoparticle production, stability, and antibacterial activity. AgNPs synthesised from plant extract had greater antibacterial activity, suggesting they could treat resistant microbial diseases. This green synthesis method complements biocompatible nanotechnology and could be used in clinical and pharmaceutical applications. This study developed an eco-friendly and effective method for making silver nanoparticles (AgNPs) from Claytonia perfoliata (R.) Nees methanolic leaf extract. The study showed that the extract's phytochemicals were excellent reducing and stabilising agents, enabling green AgNP production and dispersion. Optimising synthesis parameters such $AgNO_3$ concentration, pH, temperature, and reaction time greatly affects nanoparticle production and quality. Synthesised AgNPs were spherical, nanoscale, and crystalline after characterisation. Importantly, biosynthesised AgNPs showed good antibacterial action against Gram-positive and Gram-negative bacterial strains, suggesting its use as an alternative antibiotic. Green nanotechnology allows for sustainable nanoparticle manufacturing and the creation of plant-based nanomedicines to treat bacterial diseases.

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