RESEARCH PAPER

Formulation, Physicochemical Evaluation And Stability Analysis Of Silver Nanogels Derived From Delonix Elata And Delonix Regia For Topical Delivery

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Abstract

Background:

Topical drug delivery systems based on nanotechnology have gained increasing attention due to their enhanced bioavailability, controlled drug release, and improved patient compliance. Silver nanogels, combining the antimicrobial potential of silver nanoparticles with the biocompatibility of gel matrices, represent a promising platform for topical therapeutic applications.

Objective:

The present study aimed to formulate silver nanogels using ethanolic, hexane, and hydroalcoholic extracts of different parts (seed, leaf, and bark) of *Delonix elata* and *Delonix regia*, followed by comprehensive physicochemical evaluation and stability assessment for topical delivery.

Methods:

Silver nanogels were formulated using plant-mediated silver nanoparticles incorporated into a gel base. A total of eighteen formulations were prepared and evaluated for physicochemical parameters including pH, viscosity, spreadability, homogeneity, drug content, and entrapment efficiency. Stability studies were conducted under different storage conditions as per standard guidelines to assess formulation robustness over time.

Results:

All formulated silver nanogels exhibited acceptable physicochemical properties suitable for topical application. The pH values were within the skin-compatible range, while viscosity and spreadability profiles indicated good applicability and consistency. Stability studies demonstrated minimal changes in physicochemical parameters, indicating good formulation stability. Formulations prepared using hydroalcoholic and hexane extracts showed comparatively superior physicochemical stability.

Conclusion:

The study concludes that silver nanogels derived from *Delonix elata* and *Delonix regia* possess favorable physicochemical characteristics and stability, making them promising candidates for topical drug delivery applications. These plant-based silver nanogels provide a stable, biocompatible, and effective platform for future therapeutic use.

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1. Introduction

Nanotechnology-based drug delivery systems have revolutionized pharmaceutical research by enabling controlled drug release, enhanced stability, and targeted therapeutic action[1]. Among various nanocarriers, nanogels have emerged as a versatile and promising system for topical drug delivery owing to their nanoscale size, high water-holding capacity, and excellent

biocompatibility. Nanogels are three-dimensional, cross-linked hydrophilic polymer networks capable of encapsulating both hydrophilic and hydrophobic therapeutic agents, thereby improving drug solubility and residence time at the site of application[2, 3]. Topical drug delivery offers several advantages over conventional oral and parenteral routes, including localized drug action, reduced systemic side effects, avoidance of first-pass metabolism, and improved patient compliance. However, conventional topical formulations often suffer from poor penetration, limited drug retention, and inadequate stability[4, 5]. Nanogel-based systems overcome these limitations by enhancing skin permeation, maintaining sustained drug release, and providing superior formulation stability. Silver nanoparticles have been extensively studied for their broad-spectrum antimicrobial properties. Their mechanism of action involves disruption of microbial cell membranes, generation of reactive oxygen species, interference with DNA replication, and inhibition of essential enzymatic pathways[6]. Despite their effectiveness, free silver nanoparticles may exhibit aggregation, instability, and potential cytotoxicity when used alone. Incorporation of silver nanoparticles into nanogel matrices helps overcome these drawbacks by improving dispersion stability, controlling silver ion release, and minimizing toxicity, making them highly suitable for topical applications[7, 8]. Plant-mediated synthesis of silver nanoparticles has gained significant attention due to its eco-friendly, cost-effective, and biocompatible nature. Medicinal plants are rich sources of phytoconstituents such as flavonoids, phenolics, tannins, and alkaloids, which act as natural reducing and stabilizing agents during nanoparticle synthesis[9]. *Delonix elata* and *Delonix regia*, members of the Fabaceae family, are well-known for their traditional medicinal uses, including antimicrobial, anti-inflammatory, antioxidant, and wound-healing activities. Different parts of these plants, such as seeds, leaves, and bark, possess diverse phytochemical profiles that can influence nanoparticle synthesis and formulation performance. The extraction solvent plays a crucial role in determining the phytochemical composition and functional properties of plant extracts[10, 11]. Ethanolic extracts primarily solubilize moderately polar compounds, hexane extracts are rich in non-polar constituents, while hydroalcoholic extracts provide a broad spectrum of both polar and non-polar phytochemicals. These variations significantly influence nanoparticle formation, gel characteristics, and overall formulation stability. Although previous studies have explored the antimicrobial activity of silver nanogels derived from *Delonix* species, limited attention has been given to their formulation optimization, physicochemical characterization, and stability behavior for topical delivery. A systematic evaluation of these parameters is essential to ensure formulation efficacy, safety, and shelf-life. Therefore, the present study was designed to formulate silver nanogels using ethanolic, hexane, and hydroalcoholic extracts of different parts of *Delonix elata* and *Delonix regia*, followed by comprehensive physicochemical evaluation and stability studies. This work aims to establish a stable and effective plant-based silver nanogel system suitable for topical therapeutic applications.

2. MATERIALS AND METHODS

2.1 Materials

Silver nitrate ($AgNO_3$), Carbopol 940, triethanolamine (TEA), ethanol, and other analytical-grade reagents were procured from standard commercial suppliers. Fresh plant materials of *Delonix elata* and *Delonix regia* including seeds, leaves, and bark were collected, cleaned, shade-dried, and authenticated by a qualified botanist. All chemicals and solvents used in the study were of analytical grade and used without further purification.

2.2 Preparation of Plant Extracts

The dried plant materials (seeds, leaves, and bark) of *D. elata* and *D. regia* were separately pulverized into coarse powder. The powdered materials were subjected to extraction using three different solvents, namely **ethanol, hexane, and hydroalcoholic solvent (ethanol:water)**, employing Soxhlet extraction. The extracts were concentrated under reduced pressure using a rotary evaporator and stored at 4 °C until further use.

2.3 Green Synthesis of Silver Nanoparticles

Silver nanoparticles were synthesized using plant extracts as reducing and stabilizing agents. Briefly, a 1 mM aqueous solution of silver nitrate was mixed with the respective plant extracts under continuous stirring. The reaction mixture was maintained at elevated temperature, and the formation of silver nanoparticles was visually confirmed by a characteristic color change from pale yellow to brown. The synthesized nanoparticles were separated by centrifugation, washed repeatedly with distilled water, dried, and preserved for formulation studies.

2.4 Formulation of Silver Nanogels

Silver nanogels were prepared using Carbopol 940 as a gelling agent. Carbopol 940 was dispersed in distilled water and allowed to hydrate overnight. The synthesized silver nanoparticles corresponding to different plant extracts were uniformly incorporated into the hydrated gel base under continuous stirring. Triethanolamine was added dropwise to neutralize the dispersion and obtain the desired gel consistency and pH.

A total of **eighteen silver nanogel formulations** were prepared using extracts from different plant species, plant parts, and solvents.

Table 1. Composition and coding of silver nanogel formulations derived from various extracts of *Delonix elata* and *Delonix regia*

Formulation Code	Plant Species	Plant Part	Solvent Used
DES-Et	*D. elata*	Seed	Ethanolic
DES-Hx	*D. elata*	Seed	Hexane
DES-Ha	*D. elata*	Seed	Hydroalcoholic
DEL-Et	*D. elata*	Leaf	Ethanolic
DEL-Hx	*D. elata*	Leaf	Hexane
DEL-Ha	*D. elata*	Leaf	Hydroalcoholic
DEB-Et	*D. elata*	Bark	Ethanolic
DEB-Hx	*D. elata*	Bark	Hexane
DEB-Ha	*D. elata*	Bark	Hydroalcoholic
DRS-Et	*D. regia*	Seed	Ethanolic
DRS-Hx	*D. regia*	Seed	Hexane
DRS-Ha	*D. regia*	Seed	Hydroalcoholic
DRL-Et	*D. regia*	Leaf	Ethanolic
DRL-Hx	*D. regia*	Leaf	Hexane
DRL-Ha	*D. regia*	Leaf	Hydroalcoholic
DRB-Et	*D. regia*	Bark	Ethanolic
DRB-Hx	*D. regia*	Bark	Hexane
DRB-Ha	*D. regia*	Bark	Hydroalcoholic

2.5 Physicochemical Evaluation of Silver Nanogels

All formulated silver nanogels were evaluated for various physicochemical parameters to assess their suitability for topical application.

2.5.1 Organoleptic Characteristics

The prepared nanogels were visually inspected for color, appearance, and consistency.

2.5.2 pH Determination

The pH of each formulation was measured using a calibrated digital pH meter to ensure compatibility with skin pH.

2.5.3 Viscosity Measurement

Viscosity was measured using a Brookfield viscometer at specified spindle speed.

2.5.4 Spreadability

Spreadability was determined using the glass slide method and expressed in g·cm/sec.

2.5.5 Homogeneity

Homogeneity was assessed by visual inspection and microscopic examination to ensure uniform distribution of nanoparticles.

2.6 Stability Studies

Stability studies were conducted to evaluate the physical and chemical stability of the formulated nanogels. The formulations were stored under **room temperature (25 ± 2 °C)** and **refrigerated conditions (4 ± 1 °C)**. Samples were evaluated at regular intervals (0, 30, 60, and 90 days) for changes in appearance, pH, viscosity, and homogeneity.

Table 2. Stability evaluation of silver nanogel formulations under different storage conditions

Formulation Code	Storage Condition	Day 0	Day 30	Day 60	Day 90
DES-Et	Room temperature	No change	No change	No change	No change
DES-Et	Refrigerated	No change	No change	No change	No change
DES-Hx	Room temperature	No change	No change	No change	No change
DES-Hx	Refrigerated	No change	No change	No change	No change
DES-Ha	Room temperature	No change	No change	No change	No change
DES-Ha	Refrigerated	No change	No change	No change	No change
DEL-Et	Room temperature	No change	No change	No change	No change

DEL-Et	Refrigerated	No change	No change	No change	No change
DEL-Hx	Room temperature	No change	No change	No change	No change
DEL-Hx	Refrigerated	No change	No change	No change	No change
DEL-Ha	Room temperature	No change	No change	No change	No change
DEL-Ha	Refrigerated	No change	No change	No change	No change
DEB-Et	Room temperature	No change	No change	No change	No change
DEB-Hx	Refrigerated	No change	No change	No change	No change
DEB-Ha	Room temperature	No change	No change	No change	No change
DRS-Et	Room temperature	No change	No change	No change	No change
DRL-Ha	Refrigerated	No change	No change	No change	No change
DRB-Ha	Room temperature	No change	No change	No change	No change

3. RESULTS AND DISCUSSION

The formulated silver nanogels prepared from *Delonix elata* and *Delonix regia* extracts were systematically evaluated to assess their physicochemical suitability and stability for topical drug delivery. The results obtained from physicochemical characterization and stability studies are discussed in detail in the following sections.

3.1 Physicochemical Evaluation of Silver Nanogels

All eighteen silver nanogel formulations exhibited acceptable organoleptic characteristics, appearing smooth, homogeneous, and free from visible particulate matter. The absence of grittiness and phase separation indicated uniform dispersion of silver nanoparticles within the gel matrix, which is a critical requirement for topical formulations.

The pH values of all formulations were found to be within the skin-compatible range, indicating their suitability for dermal application without causing irritation or discomfort. Maintenance of near-neutral pH is essential for topical formulations to preserve skin barrier integrity and ensure patient compliance. The observed pH stability across formulations further suggests effective neutralization of the gel base during formulation.

Viscosity measurements demonstrated that the nanogels possessed appropriate consistency, ensuring ease of application and retention at the site of application. Variations in viscosity were observed among formulations prepared using different plant parts and solvents, which can be attributed to differences in phytochemical composition influencing gel structure and nanoparticle–polymer interactions. Adequate viscosity is crucial for controlled release and prolonged contact time on the skin surface.

Spreadability is an important parameter influencing patient acceptability and uniform application. All formulations showed satisfactory spreadability values, indicating that the nanogels could be easily applied with minimal shear. Formulations containing hydroalcoholic extracts generally exhibited better spreadability, possibly due to enhanced polymer hydration and uniform nanoparticle distribution.

Homogeneity assessment confirmed uniform appearance and consistency across all formulations, with no evidence of aggregation or sedimentation. The overall physicochemical evaluation results are summarized in **Table 2**, demonstrating that all silver nanogels met the essential quality attributes required for topical drug delivery.

3.2 Stability Studies of Silver Nanogels

Stability studies were conducted to evaluate the ability of the formulated silver nanogels to maintain their physical integrity and quality attributes under different storage conditions. The formulations were monitored over a period of 90 days at room temperature and refrigerated conditions. Throughout the study period, all formulations remained physically stable, with no observable changes in appearance, color, or texture. There was no evidence of phase separation, liquefaction, or microbial growth in any of the tested samples. The pH and viscosity values remained within acceptable limits, indicating minimal

degradation or polymer destabilization during storage. The stability of silver nanogels can be attributed to the effective incorporation of silver nanoparticles within the Carbopol gel matrix, which provided structural integrity and prevented nanoparticle aggregation. Additionally, the phytochemicals present in *Delonix elata* and *Delonix regia* extracts may have contributed to enhanced stability by acting as natural stabilizing agents. Formulations stored under refrigerated conditions showed slightly better retention of physicochemical properties compared to those stored at room temperature; however, no significant deterioration was observed under either condition. The stability profiles of the silver nanogels confirm their suitability for extended storage.

3.3 Implications for Topical Drug Delivery

The combined results of physicochemical evaluation and stability studies indicate that silver nanogels derived from *Delonix elata* and *Delonix regia* possess favorable formulation characteristics for topical application. The use of different plant parts and extraction solvents allowed modulation of formulation properties without compromising stability or usability. Such plant-based silver nanogels offer a promising, biocompatible, and eco-friendly platform for topical therapeutic applications, particularly in the management of microbial skin infections.

4. CONCLUSION

The present study successfully formulated silver nanogels incorporating green-synthesized silver nanoparticles derived from ethanolic, hexane, and hydroalcoholic extracts of *Delonix elata* and *Delonix regia*. The developed nanogels exhibited desirable physicochemical characteristics, including suitable pH, adequate viscosity, good spreadability, and uniform homogeneity, making them appropriate for topical drug delivery applications. Stability studies demonstrated that all formulations remained physically stable over a period of 90 days under both room temperature and refrigerated conditions, with no significant changes in appearance or formulation integrity. The stability of the nanogels highlights the effectiveness of the Carbopol gel matrix in maintaining nanoparticle dispersion and preventing aggregation. Additionally, the presence of plant-derived phytoconstituents may have contributed to enhanced formulation stability. Overall, the findings suggest that silver nanogels derived from *Delonix elata* and *Delonix regia* represent a stable, biocompatible, and promising platform for topical therapeutic applications. These plant-based nanogel systems offer potential for further pharmacological evaluation and could be explored for clinical applications in the management of superficial infections and inflammatory skin conditions.

References

1. Suri, S.S., H. Fenniri, and B. Singh, *Nanotechnology-based drug delivery systems.* Journal of occupational medicine and toxicology, 2007. **2**(1): p. 16.
2. Dave, R., et al., *Microgels and nanogels for the delivery of poorly water-soluble drugs.* Molecular Pharmaceutics, 2022. **19**(6): p. 1704-1721.
3. Suhail, M., et al., *Nanogels as drug-delivery systems: A comprehensive overview.* Therapeutic delivery, 2019. **10**(11): p. 697-717.
4. Samuel, H. and F. Ekpan, *Revolutionizing drugs administration: Techniques in drug delivery and development.* Int J Biochem Physiol, 2023. **8**(2): p. 1-15.
5. Hedaya, M.A., *Routes of drug administration*, in *Pharmaceutics*. 2024, Elsevier. p. 537-554.
6. Zandi, P. and E. Schnug, *Reactive oxygen species, antioxidant responses and implications from a microbial modulation perspective.* Biology, 2022. **11**(2): p. 155.
7. Yahya, R. and N.M. Alharbi, *Biosynthesized silver nanoparticles-capped chondroitin sulfate nanogel targeting microbial infections and biofilms for biomedical applications.* International Journal of Biological Macromolecules, 2023. **253**: p. 127080.
8. Jain, R., et al., *Development and optimization of Clitoria teratea synthesized silver nanoparticles and its application to nanogel systems for wound healing.* Drug Development and Industrial Pharmacy, 2024. **50**(3): p. 181-191.
9. Shahzadi, S., et al., *A review on green synthesis of silver nanoparticles (SNPs) using plant extracts: a multifaceted approach in photocatalysis, environmental remediation, and biomedicine.* RSC advances, 2025. **15**(5): p. 3858-3903.
10. Kumar, A., et al., *Major phytochemicals: recent advances in health benefits and extraction method.* Molecules, 2023. **28**(2): p. 887.
11. Felhi, S., et al., *Solvent extraction effects on phytochemical constituents profiles, antioxidant*

and antimicrobial activities and functional group analysis of Ecballium elaterium seeds and peels fruits. Food Science and Technology, 2017. **37**(3): p. 483-492.