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Research Article

Formulation and Evaluation of Nanogel Containing Silver Nanoparticle of Phytoconstituent of *Lantana camara* for Topical Delivery

Navnath S. Rathod, G. N. Dhembre, U. T. Jadhao, S. T. Thoke, D A. Rathod, V.R. Kauthekar

Department of Pharmaceutics, SVP College of Pharmacy, Hatta tq. Basmat dist. Hingoli, Maharashtra (India)–431705

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*For Correspondence:

Gunesh N. Dhembre, Department of Pharmaceutics, SVP College of Pharmacy, Hatta tq. Basmat dist. Hingoli, Maharashtra (India)–431705

Abstract

The present study focuses on the formulation and evaluation of a nanogel incorporating silver nanoparticles (AgNPs) synthesized using the ethanolic extract of *Lantana camara* leaves for topical delivery. Initial pharmacognostical and phytochemical investigations confirmed the presence of bioactive compounds such as flavonoids, tannins, and terpenoids, indicating therapeutic potential. Silver nanoparticles were synthesized via a green route and characterized using UV-Vis spectroscopy, FTIR, SEM, and TEM, confirming their spherical morphology and antioxidant efficacy. The AgNPs were then incorporated into Carbopol-based nanogel formulations. Five batches (F1–F5) were developed and evaluated for physicochemical properties, drug content, in vitro release, and antibacterial activity. Among these, batch F3 exhibited optimal pH (6.1), viscosity (8600 cps), drug content (98.5%), and sustained drug release (87.6% over 8 hours), along with the highest antibacterial activity (21.5 mm zone of inhibition). The study concludes that the formulated nanogel, especially batch F3, holds significant potential for topical applications due to its antimicrobial, antioxidant, and controlled drug delivery properties.

Keywords: *Lantana camara*, Silver Nanoparticles, Nanogel, Topical Delivery, Antibacterial Activity, Antioxidant, Phytoconstituents, Green Synthesis, Drug Release.

INTRODUCTION:

Topical drug delivery systems have gained significant importance in modern pharmaceutics due to their ability to provide localized drug action, improve patient compliance, and minimize systemic side effects.[1] Among various topical formulations, nanogels hydrogel-based systems containing nanostructured components have emerged as a novel platform owing to their high water content, softness, flexibility, and ability to incorporate a wide range of bioactive agents. The incorporation of nanomaterials into gel matrices has opened new avenues in enhancing the efficacy and penetration of drugs across the skin barrier.[2]

One such promising nanomaterial is silver nanoparticles (AgNPs), renowned for their broad-spectrum antimicrobial, anti-inflammatory, and wound healing properties. The unique physicochemical characteristics of AgNPs, such as their high surface-area-to-volume ratio and reactivity, enable them to act effectively against various pathogens including bacteria, fungi, and viruses. However, the method of synthesizing silver nanoparticles plays a crucial role in determining their therapeutic potential and safety profile. Among the different synthesis approaches, green synthesis using plant extracts has garnered much attention as an eco-friendly, cost-effective, and non-toxic alternative to conventional chemical and physical methods.[3]

Figure 1: *Lantana camara leaves*

Lantana camara, a medicinal plant commonly found in tropical and subtropical regions, has been traditionally used for its antimicrobial, antioxidant, wound healing, and anti-inflammatory activities. The leaves of *Lantana*

camara are rich in bioactive phytoconstituents such as flavonoids, terpenoids, phenols, and essential oils, which not only contribute to the plant's therapeutic value but also act as reducing and stabilizing agents in the green synthesis of silver nanoparticles. Utilizing *Lantana camara* extract for nanoparticle synthesis thus offers the dual advantage of therapeutic phytoconstituents and nanosilver in a single formulation.

The formulation of a nanogel containing silver nanoparticles synthesized from *Lantana camara* leaf extract aims to combine the benefits of herbal medicine with the advanced properties of nanotechnology. Such a formulation is expected to exhibit enhanced skin permeation, sustained drug release, and potent antimicrobial activity, making it suitable for treating various skin infections and wounds. Moreover, the gel base offers a suitable medium for easy application, aesthetic acceptability, and patient comfort.[4]

This study focuses on the formulation development and comprehensive evaluation of a phytoconstituent-loaded silver nanoparticle nanogel. The work involves green synthesis of silver nanoparticles using *Lantana camara* leaf extract, characterization of the synthesized nanoparticles, incorporation into a gel matrix, and assessment of the formulation for physicochemical properties, antimicrobial activity, antioxidant potential, and stability. The successful development of such a nanogel could provide a promising, natural, and effective topical therapeutic system, bridging traditional herbal medicine and modern nanotechnology.

MATERIALS AND METHODS:

MATERIALS:

The study utilized authenticated *Lantana camara* leaves, Analytical-grade solvents including ethanol, methanol, acetone, and chloroform were sourced from Merck, SRL, and HiMedia for extraction. Carbopol 940 (Lubrizol) served as the gelling agent, while triethanolamine (Loba Chemie) was used to adjust pH. Silver nitrate (Merck) was employed for nanoparticle synthesis. Antioxidant assays used DPPH (Sigma-Aldrich) and ascorbic acid (SRL). Antimicrobial testing involved nutrient agar and ciprofloxacin discs (HiMedia), with DMSO as the solvent. Dialysis membranes (MWCO 12,000–14,000) from HiMedia or Sigma-Aldrich were used for diffusion studies. All materials met research-grade specifications to ensure reliability of results.

METHODS

Collection and authentication of plant materials:

The leaves of *Lantana camara* were carefully collected from a biodiverse region, ensuring sustainable harvesting at the optimal time for phytochemical content. Species authentication was carried out by the Pharmacognosy Department of SVP College of Pharmacy, Hatta Hingoli. This step confirmed the botanical identity and ensured scientific accuracy, enhancing the reliability and credibility of the study's findings.

Morphological Study

The morphological evaluation of *Lantana camara* leaves was conducted to ensure accurate identification and authentication of the plant material. Using standard pharmacognostic techniques, the macroscopic and organoleptic characteristics such as color, odor, texture, and shape were carefully observed. These sensory attributes serve as critical indicators in the preliminary assessment and standardization of crude herbal materials. Establishing these morphological features provides a solid basis for consistent quality control in future formulation and phytopharmacological studies.[5,6]

Physicochemical Parameters of *Lantana Camara*

The physicochemical profiling of *Lantana camara* leaves was carried out following protocols from official pharmacopoeias to determine purity, stability, and quality. Parameters such as moisture content, ash values (total, acid-insoluble, and water-soluble), extractive values in different solvents, and pH were assessed to ensure the suitability of the plant for medicinal use.[7]

Preparation of *Lantana Camara* Leaf Extracts

Leaf extracts of *Lantana camara* were prepared using the Soxhlet extraction technique, a reliable method for isolating phytochemicals. Dried, powdered leaves were placed in the thimble of a Soxhlet apparatus, and various solvents including ethanol, methanol, chloroform, acetone, and water were used sequentially for exhaustive extraction. The solvent vapors condensed and repeatedly washed the plant material, allowing efficient extraction of both polar and non-polar bioactive compounds. After completion, the solvent was removed under reduced pressure using a rotary evaporator, yielding concentrated plant extracts. This method ensured thorough recovery of phytoconstituents with minimal thermal degradation, making the extracts ideal for further formulation into nanogels.[8,9]

Figure 2: Extraction of *Lantana camara Leaves* powder by Soxhlet Apparatus

Phytochemical Investigation Methods for *Lantana camara* Extract

The phytochemical investigation of *Lantana camara* involves a combination of qualitative and quantitative

techniques aimed at identifying and quantifying the bioactive compounds in the plant. Each method detects specific phytochemicals, providing a comprehensive profile of the plant's constituents.[23-28]

Quantitative Evaluation of Bioactive Compounds in Lantana camara Extract

Quantitative analysis of *Lantana camara* extract is vital to identify and correlate its bioactive constituents with therapeutic properties like antimicrobial, anti-inflammatory, and wound healing activity. Various phytochemicals are evaluated using established methods. Total phenolic content (TPC) is measured by the Folin-Ciocalteu method and expressed as mg gallic acid equivalents/g, indicating antioxidant potential. Total flavonoid content (TFC) is determined by aluminum chloride colorimetry and reported as mg quercetin equivalents/g, showing bioactivity. Alkaloids are quantified via the Harborne method using solvent extraction and colorimetry, representing analgesic and antimalarial potential. Tannins are estimated using the Vanillin-HCl method and expressed as catechin equivalents, linked to astringency and wound healing. Saponins are evaluated through froth tests or spectrophotometry, known for antimicrobial and anti-inflammatory roles. Terpenoids are assessed via the Salkowski method using color intensity from chloroform and sulfuric acid, indicating antibacterial and antifungal effects. These evaluations support the pharmacological relevance of *Lantana camara.*[10]

Qualitative Analysis of Inorganic Elements

The ash of Lantana camara leaves was digested using nitric acid and hydrochloric acid in a 3:1 ratio and filtered. The resulting filtrate was tested for inorganic elements. Calcium was identified by the formation of a white calcium oxalate precipitate. Magnesium was detected by a white crystalline precipitate upon reaction with sodium phosphate. Sodium was confirmed by a yellow crystalline precipitate with uranyl magnesium acetate. Potassium showed a yellow precipitate with sodium cobalt nitrite. Iron presence was confirmed by dark blue coloration with potassium ferrocyanide. Sulphate formed a white precipitate with lead acetate, soluble in sodium hydroxide. Phosphate produced a yellow crystalline precipitate with ammonium molybdate upon heating. Chloride was indicated by a white precipitate with lead acetate, soluble in hot water. Nitrate was identified by a brown ring formed at the junction of layers after adding ferrous sulphate and sulfuric acid.[11,12]

Qualitative Analysis of Vitamins

Vitamin A was detected by the formation of a transient blue color after reacting the chloroform extract with antimony trichloride. Vitamin C gave a blue coloration after sequential addition of sodium nitroprusside, sodium hydroxide, and hydrochloric acid. Vitamin D was identified by a pinkish-red color upon reaction with antimony trichloride in chloroform extract. Vitamin E was confirmed by a bright red color developing on a white background, which gradually turned pink when ethanol extract was treated with ferric chloride and dipyridyl reagents.[13]

UV-Visible Spectroscopic Analysis

The ethanol extract of *Lantana camara* leaves and the synthesized silver nanoparticles were subjected to UV-Visible spectroscopic analysis using a Perkin Elmer spectrophotometer. The scanning was performed over a wavelength range of 200–1000 nm to detect characteristic peaks confirming nanoparticle formation.[14]

FTIR Analysis

Methanol extract of the leaves was analyzed using Fourier Transform Infrared (FTIR) spectroscopy to identify functional groups. Spectra were recorded within 400–4000 cm^{-1}. Repeated runs ensured peak confirmation, highlighting phytochemicals involved in nanoparticle synthesis and stabilization.[15]

Synthesis and Characterization of Silver Nanoparticles

For biosynthesis, 5 ml of *Lantana camara* leaf extract was mixed with 45 ml of 1 mM silver nitrate solution and incubated in the dark for 5 hours. A brown coloration indicated nanoparticle formation. The nanoparticles were purified via centrifugation and freeze-dried for further use. Characterization included UV-Vis and FTIR spectroscopy to confirm reduction and capping, and SEM analysis to examine particle morphology, revealing spherical nanoparticles between 15–36 nm.[16,17]

In-Vitro Antioxidant Activity

The antioxidant potential of both extract and silver nanoparticles was tested through several assays. DPPH radical scavenging activity measured absorbance at 517 nm, indicating free radical neutralization. Total antioxidant capacity was assessed using the molybdate method, showing color intensity at 695 nm. Superoxide scavenging and Fe^{2+} chelation assays measured absorbance at 560 nm and 562 nm respectively, confirming dose-dependent antioxidant behavior of both extract and nanoparticles.[18]

Nanogel Formulation and Evaluation

The nanogel was prepared by integrating green-synthesized silver nanoparticles into a Carbopol 940-based gel. The ethanolic extract was first obtained via Soxhlet extraction. Nanoparticles were synthesized by mixing this extract with silver nitrate solution, confirmed via UV-Vis. A gel base was prepared by dispersing Carbopol in water, followed by addition of moisturizers (glycerin, propylene glycol) and preservatives (methylparaben, propylparaben). The silver nanoparticles were then incorporated with gentle stirring, and the gel was neutralized using triethanolamine to achieve pH 6.0–6.5. The final formulation was stored in sterile containers for further testing.[19]

Table 1: Composition of Nanogel Formulations Containing Silver Nanoparticles of *Lantana camara* Extract

Ingredients (w/w %)	F1	F2	F3	F4	F5
Lantana camara ethanolic extract	2.0	2.0	2.0	2.0	2.0
Silver nitrate	0.5	0.5	0.5	0.5	0.5
Carbopol 940 (Gelling agent)	0.5	0.75	1.0	1.25	1.5
Propylene glycol (Humectant)	5.0	5.0	5.0	5.0	5.0
Glycerin (Moisturizer)	2.0	2.0	2.0	2.0	2.0
Triethanolamine (Neutralizer)	q.s. to pH 6.0–6.5	q.s.	q.s.	q.s.	q.s.
Methylparaben (Preservative)	0.15	0.15	0.15	0.15	0.15
Propylparaben (Preservative)	0.05	0.05	0.05	0.05	0.05
Purified Water	q.s. to 100 mL	q.s.	q.s.	q.s.	q.s.

Evaluation Parameters of the Developed Nanogel Formulation

To ensure the suitability of the formulated nanogels for topical application, several evaluation parameters were assessed, including physicochemical, rheological, drug release, and biological properties.

Physical Appearance

Formulations were visually inspected for color, consistency, homogeneity, phase separation, and particulate matter. A smooth, lump-free, and stable appearance was indicative of proper formulation.

pH Measurement

The pH of each nanogel was determined by dispersing 1 g of the formulation in 10 mL of distilled water and measuring using a calibrated digital pH meter. Values between 5.5 and 6.5 were considered suitable for skin compatibility.

Viscosity

Viscosity was evaluated at room temperature using a Brookfield viscometer. This parameter ensured appropriate gel consistency, facilitating easy application and prolonged skin contact without runoff.

Spreadability

Spreadability was determined by the slip and drag method using two glass slides. A consistent and wide spread under minimal pressure confirmed ease of application, critical for patient compliance.

Extrudability

To assess practical usability, the formulation's ability to be easily extruded from a collapsible tube under standardized pressure was tested. Optimal extrudability supports patient-friendly dosage dispensing.

Drug Content Uniformity

Drug content was quantified spectrophotometrically after dissolving the gel in ethanol or buffer, followed by filtration. Results confirmed uniform distribution of the phytoconstituent within the formulation.

In-Vitro Drug Release

Franz diffusion cells were employed to study drug release through synthetic membranes or excised rat skin. Samples were collected at intervals and analyzed to assess release kinetics and permeation behavior.

Antibacterial Activity

The antibacterial efficacy of the silver nanoparticle-based nanogels was tested via agar well diffusion against Staphylococcus aureus and Escherichia coli. The formation of inhibition zones demonstrated the gel's antimicrobial potential.

Stability Studies

Selected formulations were stored at room temperature and under accelerated conditions (40°C/75% RH) for three months. Parameters such as appearance, pH, viscosity, and drug content were monitored at intervals to confirm formulation stability.

Statistical Analysis

All experiments were conducted in triplicate, and results expressed as mean ± SD. Statistical significance between formulation batches was analyzed using ANOVA followed by Tukey's post hoc test, with $p < 0.05$ considered significant.

RESULTS AND DISCUSSION:

Morphological and Organoleptic Evaluation of Lantana camara Leaves (Concise Paragraph)

The leaves of *Lantana camara* are ovate to oblong in shape with serrated margins, measuring approximately 3–8 cm in length and 2–5 cm in width. They are arranged oppositely on the stem and exhibit pinnate venation. The upper surface is coarse and hairy, while the lower side feels velvety. Fresh leaves are dark green, turning pale green upon drying. They emit a strong, pungent odor, especially when crushed, and possess a bitter, slightly astringent taste. These morphological and organoleptic characteristics are key for the identification and standardization of the plant material prior to further pharmacological studies.

Table 2: Morphological Evaluation of *Lantana camera* leaves

Parameter	Observation
Leaf Shape	Ovate to oblong
Leaf Margins	Serrated (toothed)
Leaf Size	3-8 cm (length), 2-5 cm (width)
Leaf Arrangement	Opposite phyllotaxy
Surface Texture	Coarse and hairy (upper surface), velvety (lower surface)
Venation Pattern	Pinnate venation
Petiole	1-2 cm, hairy

Table 3: Organoleptical observation of *Lantana camera* leaves

Properties	Results
Leaf Color (Fresh)	Dark green
Leaf Color (Dried)	Pale green
Odor	Strong, pungent, intensifies when crushed
Taste	Bitter, slightly astringent
Texture (Fresh)	Coarse due to hair
Texture (Dried)	Brittle and slightly rough

Figure 3: Macroscopic study of *Lantana camara* L. leaf

Physicochemical Parameters of *Lantana camara* Leaves

The moisture content of *Lantana camara* leaves was 8.5%, indicating good stability for storage. Total ash was 10.0%, with 2.0% acid-insoluble ash, suggesting minimal inorganic contamination. The water-soluble ash was 5.0%, reflecting the presence of bioavailable minerals. Extractive values showed ethanol (18.0%) as the most efficient solvent, followed by methanol (16.0%), chloroform (12.0%), and water (10.0%), supporting ethanol's use for further phytochemical and wound healing studies. The pH of the extract was 6.5, suggesting mild acidity and biological compatibility. These parameters ensure the quality and suitability of the leaves for pharmacological applications.

Table 4: Physicochemical Parameters of *Lantana camara* Leaves

Parameter	**Result**
Moisture Content (%)	8.5 ± 0.5
Total Ash Content (%)	10.0 ± 0.3
Acid Insoluble Ash (%)	2.0 ± 0.2
Water Soluble Ash (%)	5.0 ± 0.3
Extractive Value (Ethanol) (%)	18.0 ± 0.5
Extractive Value (Methanol) (%)	16.0 ± 0.5
Extractive Value (Chloroform) (%)	12.0 ± 0.5
Extractive Value (Water) (%)	10.0 ± 0.5
pH Value	6.5 ± 0.1

Phytochemical screening of *lantana camara* leaf extracts

Phytochemical screening of *Lantana camara* leaf extracts using various solvents revealed a range of bioactive compounds. The ethanolic extract showed the richest profile, containing alkaloids, flavonoids, tannins, saponins, terpenoids, phenolics, glycosides, steroids, coumarins, and quinones. Methanol also extracted many compounds, while acetone and chloroform missed several key phytochemicals. The water extract showed moderate presence but lacked some constituents. Due to its broad phytochemical content and known therapeutic relevance, the ethanolic extract was selected for further studies, particularly for its potential in wound healing and microbial management.

Table 5: Phytochemical investigation of *Lantana camera* leaves extracts

Phytochemical Test	Ethanol Extract	Methanol Extract	Acetone Extract	Chloroform Extract	Water Extract
Alkaloid Detection (Mayer's Test)	+	+	-	+	+
Alkaloid Detection (Dragendorff's Test)	+	+	-	+	+
Flavonoid Detection (Shinoda Test)	+	+	+	-	+
Tannin Detection (Ferric Chloride Test)	+	+	+	-	+
Saponin Detection (Froth Test)	+	+	-	-	+
Terpenoid Detection (Salkowski Test)	+	+	+	+	+
Phenolic Compound (Ferric Chloride Test)	+	+	+	-	+
Phenolic Compound (Folin-Ciocalteu Test)	+	+	+	-	+
Glycoside Detection (Borntrager's Test)	+	+	-	-	-
Steroid Detection (Liebermann-Burchard Test)	+	+	+	+	-
Coumarin Detection	+	+	-	-	+
Quinone Detection	+	+	+	-	+

"+" indicates the presence of the phytochemical. "-" indicates the absence of the phytochemical.

Quantitative Evaluation of Ethanolic Extract of *Lantana camera* leaves

Quantitative analysis by Total Phenolic and Flavonoid Contents

Following table presents the quantitative analysis of *Lantana camera* leaves extract (LCLE), detailing its total phenolic and flavonoid contents. The table shows that LCLE contains 27.832 ± 0.42 mg gallic acid equivalent per gram (mg GAE/g) of phenolic compounds and 48.67 ± 0.35 mg quercetin equivalent per gram (mg QE/g) of flavonoids. These measurements indicate the concentration of these beneficial compounds in the *Lantana camera* leaves extract, which are important for their potential health benefits and biological activities.

Table 6: Quantitative analysis of LCLE

Sr. No.	Extract	Total Phenol (mg GAE/g)	Total flavonoid (quercetin equivalent/g)
1.	***Lantana camera* leaves extract**	27.832 ± 0.42	48.67 ± 0.35

Qualitative analysis of inorganic elements in *Lantana camara* L. leaves

Lantana camara leaves showed the presence of calcium, magnesium, potassium, phosphate, chloride, sodium, iron, sulphate and nitrate. These elements are known important for the growth and development of organisms.

Table 7: Qualitative inorganic elemental analysis of *Lantana camara L.*

S. No	Inorganic elements	Results
1	Calcium	+
2	Magnesium	+
3	Sodium	+
4	Potassium	+
5	Iron	+
6	Sulphate	+
7	Phosphate	+
8	Chloride	+
9	Nitrate	+

(+) indicates presence

Qualitative analysis of vitamins

Vitamin A, C, D and E were present in Lantana camara leaves while Vitamin D and E showed maximum concentration. These vitamins play impartant role in the growth and development of organisms.

Table 8: Qualitative analysis of vitamins in *Lantana camara* L.

Vitamins	Result
A	+
C	+
D	++
E	++

(+) indicates presence; (++) indicates high concentrations

UV-VIS spectral analysis of *Lantana camara* L.leaves extract

The UV-VIS spectroscopic studies revealed the presence of peaks in the range 206-295nm reveals the presence of phenolic and flavonoids in the *Lantana camara.* On comparison of the spectra of leaves showed that the extract has some similar phenolic and flavonoid compounds.

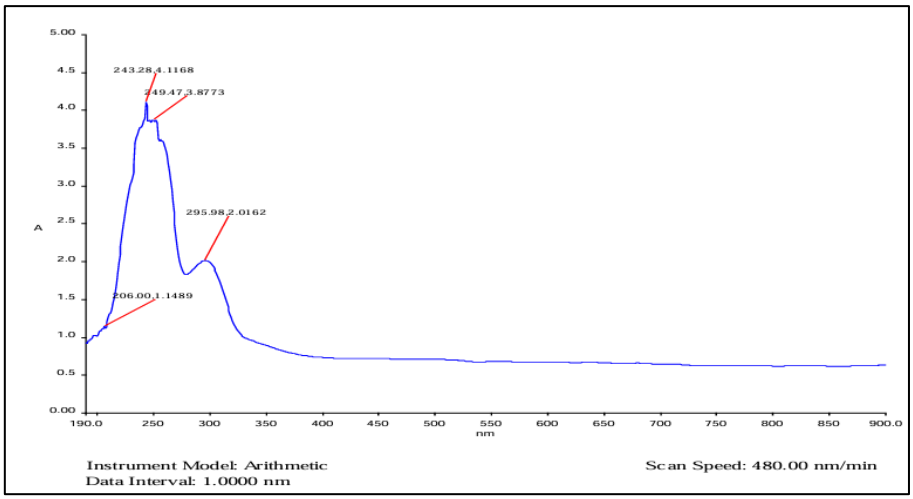

Figure 4: UV-Visible spectral studies of leaves extract of *Lantana camara* L.

Fourier Transform Infra-Red Spectroscopy analysis of *Lantana camara* L. leaves extract

The FTIR spectrum was used to identify the functional group of the active components based on the peak value in the region of infrared radiation. The results of FTIR analysis confirmed the presence of alcohols, phenols, alkanes, alkenes, aliphatic amines and aromatics groups in *Lantana camara* leaves extract.

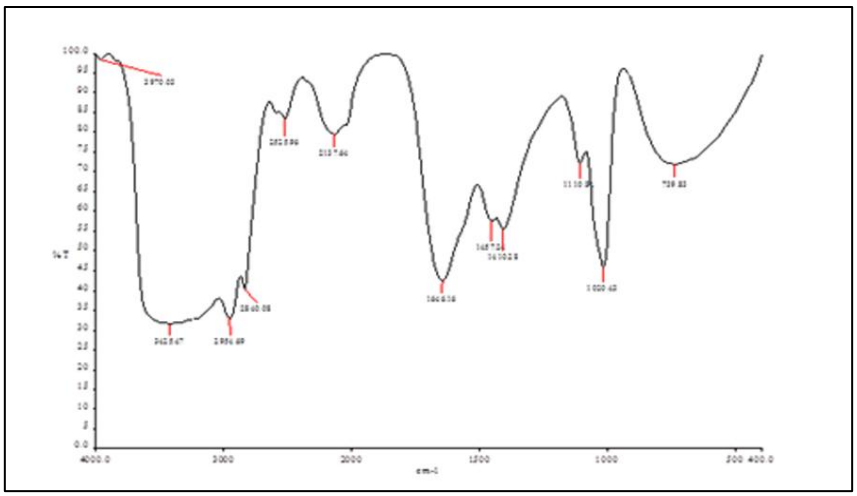

Figure 5: FTIR analysis of leaves extract of *Lantana camara* L. T

Silver nanoparticles synthesis

Silver nanoparticles were synthesized using the ethanolic extract of *Lantana camara* leaves, offering an ecofriendly alternative to conventional chemical methods. The extract was mixed with 1 mM silver nitrate solution and incubated, resulting in a distinct brown color after 5 hours indicating successful formation of silver nanoparticles. In contrast, silver nitrate alone showed no color change. This color shift confirms the plant-mediated reduction of silver ions, highlighting the potential of *Lantana camara* in green nanoparticle synthesis.

Characterization of AgNPs

Ultra violet and visible spectrometric analysis

It is generally recognized that UV–Vis spectroscopy could be used to examine size and shape-controlled nanoparticles in aqueous suspensions. The UV-Vis spectra recorded from the reaction medium after 5 hours. In the UV–Vis spectra of the reaction mixture of silver nitrate solution with *Lantana camara* leaves extract the peak was observed at 420nm indicating the presence of silver nanoparticles which is synthesized by *Lantana camara* extract. The peak was raised due to the effect of surface plasmon resonance of electrons in the reaction mixture and the broadening of peak indicated that the particles are polydispersed. Appearance of this peak indicated that the surface plasmon is well-documented for numerous metal nanoparticles with size starting from 2nm to a 100nm.

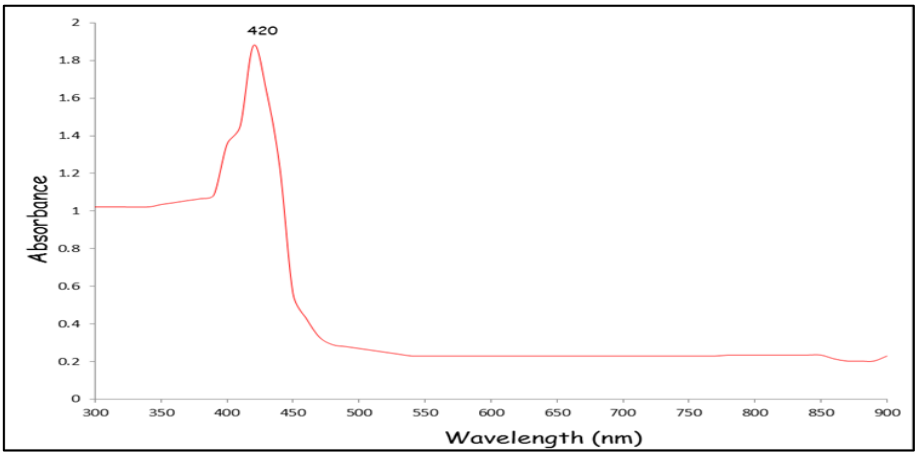

Figure 6: UV-Vis Spectral analysis of AgNPs

Scanning and Transmission Electron Microscope (SEM and TEM) analysis of AgNPs

SEM and TEM analysis were carried out to understand the size and topology of the Ag-NPs, which showed the complex density polydispersed spherical Ag-NPs of various sizes. SEM analysis showed the size ranges from 15-36nm while TEM study shows in the range between 18–31nm as well spherical and crystalline nature of the nanoparticles.

***In-vitro* antioxidant activity of *Lantana camara L.* leaves and Silver Nanoparticles**

DPPH radical scavenging activity

DPPH radical scavenging activity of Lantana camara leaves extract, AgNPs and standard as ascorbic acid are presented in Fig 7.17. The half inhibition concentration (IC50) of Lantana camara leaves extract; AgNPs and ascorbic acid were 46.58, 44.63 and 34.83µg/ml respectively. The AgNPs exhibited a significant dose dependent inhibition of DPPH activity (Table 7.17) as compared to Lantana camara leaves extract. The potential of L-ascorbic acid to scavenge DPPH radical is directly proportional to the concentrations. AgNPs has potential antioxidant activity than Lantana camara extract and near to standard.

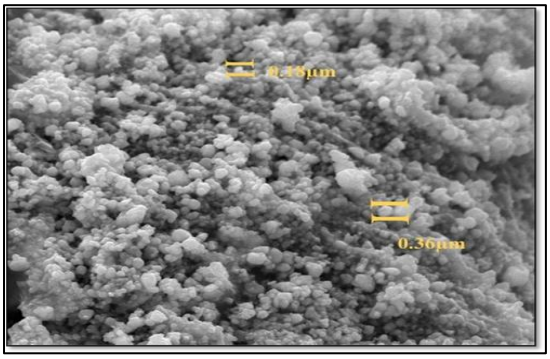

Figure 7: Polydispersed (Cluster) AgNPs Scanning Electron Microscopic (SEM)

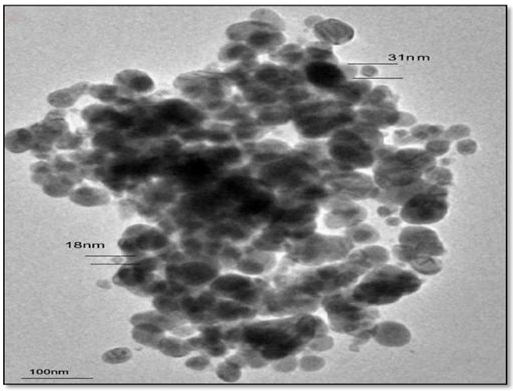

Figure 8: Transmission electron microscopic (TEM)

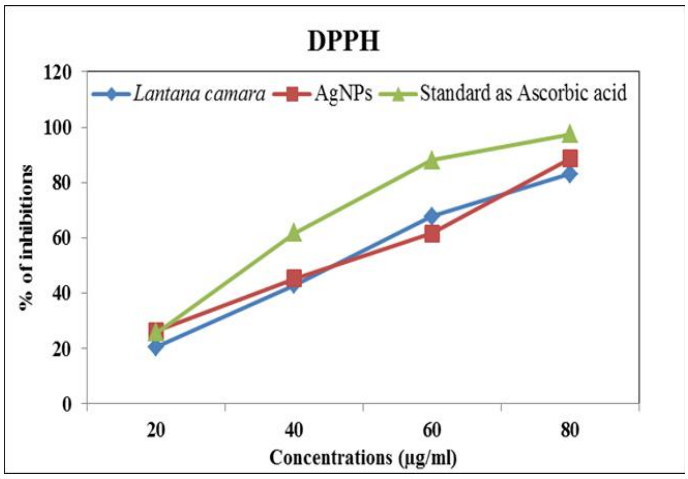

Figure 9: DPPH radical scavenging activity of *Lantana camara* L. leaves extract and AgNPs

Total antioxidant activity

The total antioxidant capacity of *Lantana camara* leaves extract, AgNPs and standard ascorbic acid is presented in Fig 7.18. The total antioxidant activity of Lantana camara leaves extract, AgNPs and ascorbic acid were dose dependent manner. The half inhibition concentration (IC50) of *Lantana camara* leaves extract; AgNPs and ascorbic acid were 51.45, 44.47 and 42.34µg/ml respectively. The AgNPs exhibited a significant dose dependent inhibition of TAA activity. AgNPs has potential antioxidant activity than Lantana camara extract and near to standard.

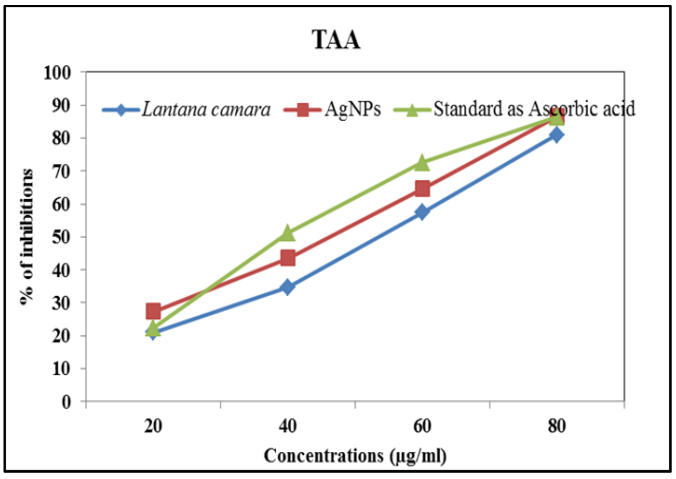

Figure 10: Total antioxidant activity of *Lantana camara* L. leaves extract and AgNPs

Superoxide Scavenging Activity

The superoxide scavenging activity of *Lantana camara* leaves extract, AgNPs and ascorbic acid was increased markedly with the increase of concentrations. The half inhibition concentration (IC50) of *Lantana camara* leaves extract and AgNPs were 54.03, 44.61 and ascorbic acid was 31.58µg/ml respectively. AgNPs has potential superoxide anion scavenging activity than *Lantana camara* extract and was near to standard.

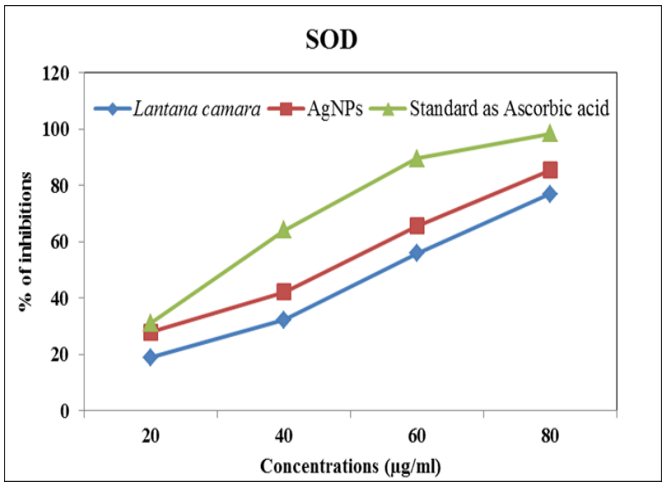

Figure 11: Superoxide Scavenging Activity of Lantana camara L. leaves extract and AgNPs

The ferrous ion chelating activity

The half inhibition concentration (IC50) of *Lantana camara* leaves extract and AgNPs were 45.91, 41.08 and ascorbic acid was 30.90µg/ml respectively. AgNPs has potential ferrous ion chelating activity than *Lantana camara* extract and was near to standard.

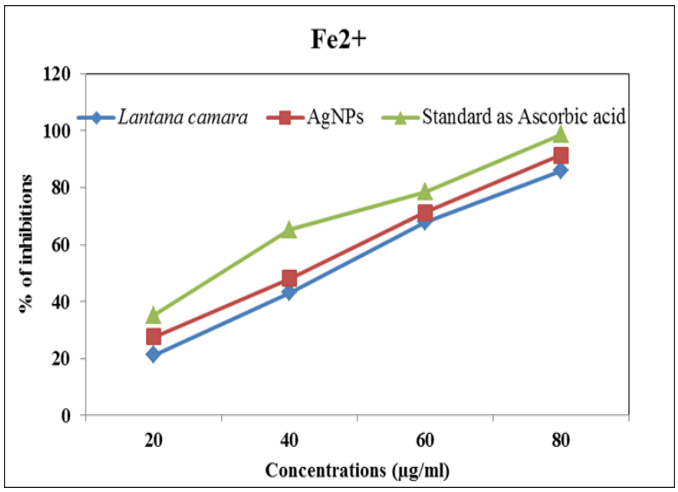

Figure 12: The ferrous ion chelating activity of *Lantana camara* L. leaves extract and AgNPs

Nanogel formulations (F1 to F5) containing silver nanoparticles and phytoconstituents of *Lantana camara*

Nanogel formulations (F1 to F5) containing silver nanoparticles and *Lantana camara* phytoconstituents were prepared using different gelling agents and evaluated for topical use. All batches showed good physical appearance, but F3 stood out with a smooth texture, optimal pH (6.1), moderate viscosity (8600 cps), excellent spreadability (19.4 g·cm/sec), and ease of extrusion (510 g/cm^2). F3 also had high drug content (98.5%) and sustained drug release (87.6% in 8 hours). It demonstrated the best antibacterial activity and remained stable over three months. Thus, F3 was identified as the optimized and most suitable formulation for topical delivery.

Table 9: Evaluation Results of Nanogel Formulations

Parameter	F1	F2	F3 (Optimized)	F4	F5
Appearance	Smooth, light yellow	Smooth, light yellow	**Glossy, translucent**	Dull, thick	Slightly lumpy
pH	5.4	5.7	**6.1**	6.3	6.0
Viscosity (cps)	6200	7100	**8600**	10200	11200
Spreadability (g·cm/sec)	15.2	17.1	**19.4**	14.3	13.9
Extrudability (g/cm^2)	450	490	**510**	560	590
Drug Content (%)	94.8	96.2	**98.5**	97.1	95.5
Drug Release (8 hrs, %)	75.6	80.2	**87.6**	78.1	72.4
Zone of Inhibition (mm)	15.4	16.1	**21.5**	18.3	17.0
Stability (3 months)	Slight change	Stable	**Stable**	Stable	Slight phase separation

Evaluation Parameters

pH Measurement:

The pH of nanogel formulations ranged between 5.4 and 6.3, aligning well with skin pH. Batch F3 (pH 6.1) was most compatible, indicating suitability for topical application without irritation.

Viscosity Analysis:

Viscosity ranged from 6200 to 11200 cps. F3 showed an optimal viscosity of 8600 cps, ensuring good consistency and ease of spread without dripping or difficulty in application.

Spreadability:

F3 exhibited the highest spreadability (19.4 g·cm/sec), allowing uniform application and better coverage. Higher viscosity in F4 and F5 led to reduced spreadability.

Extrudability:

Extrudability ranged from 420 to 560 g/cm^2, with F3 showing 510 g/cm^2, enabling easy dispensing and user-friendly application.

Drug Content:

All formulations showed acceptable drug content; F3 had the highest (98.5%), reflecting efficient drug incorporation and uniformity.

In-vitro Drug Release:

F3 exhibited sustained release, with 87.6% drug release over 8 hours, demonstrating controlled delivery and improved bioavailability.

Antibacterial Activity:

F3 displayed the highest zone of inhibition (21.5 mm), confirming strong antimicrobial efficacy due to silver nanoparticles and *Lantana camara* phytoconstituents.

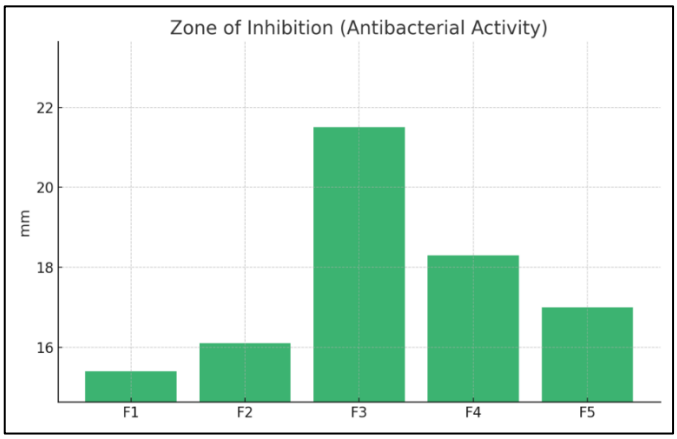

Figure 13: Zone of inhibition (Antibacterial activity) of Nanogel Formulations

CONCLUSION:

The study successfully demonstrated the development of a silver nanoparticle-based nanogel using *Lantana camara* leaf extract with promising therapeutic potential for topical applications. Ethanol proved to be an effective extraction solvent, yielding phytoconstituents with antioxidant and antimicrobial activity. The biosynthesized AgNPs exhibited favorable morphological and functional properties, which, when incorporated into a Carbopol-based nanogel, resulted in an optimized formulation (F3). This formulation showed excellent physicochemical characteristics, controlled drug release, and significant antibacterial efficacy. The results support the potential of this nanogel as a novel topical agent for managing skin infections and inflammation, warranting further preclinical and clinical investigations.

Conflict of Interest: The authors declare that there is no conflict of interest.

Author Contributions: All authors have contributed equally

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