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Phytogenic Fabrication And Characterization Of Silver Nanoparticles Using Allium Sativum And Curcuma Longa For Treating Bacterial Skin Infections Caused By Resistant Pathogens

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Abstract
The rise in antibiotic-resistant bacterial skin infections has intensified the need for alternative, sustainable therapeutic strategies. This study aimed to synthesize silver nanoparticles (AgNPs) using aqueous extracts of Allium sativum (garlic) and Curcuma longa (turmeric), and to evaluate their antibacterial activity against common dermatitis-causing pathogens. A green synthesis approach was employed, wherein 10 mL of each plant extract or their combination was added to 90 mL of 1 mM $AgNO_3$ *solution. The formation of AgNPs was visually confirmed by a color change and further validated by UV-Vis spectroscopy, FTIR, TEM, DLS, and zeta potential analyses. The synthesized nanoparticles were spherical, stable, and ranged from 16.8 to 21.4 nm in size. FTIR revealed the involvement of phenolic and amide groups in nanoparticle stabilization. Antibacterial activity, assessed using the agar well diffusion method, showed that all AgNPs exhibited significant inhibitory effects against Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa, with the combined extract-based AgNPs (F3) demonstrating superior efficacy. These findings suggest that the eco-friendly synthesis of silver nanoparticles using medicinal plants can produce biocompatible antimicrobial agents suitable for treating bacterial dermatitis. Further research on formulation development and in vivo validation is warranted for clinical translation.*
Keywords: *Green synthesis, Silver nanoparticles, Allium sativum, Curcuma longa, Antibacterial activity, Bacterial dermatitis, Eco-friendly nanotechnology, Phytogenic nanoparticles, Nanoparticle-based eco-friendly therapy.*

1. INTRODUCTION
Bacterial skin infections represent a significant global health concern, affecting millions of people each year and placing a substantial burden on healthcare systems. These infections can range in severity from superficial skin irritation, such as folliculitis and impetigo, to deeper, chronic forms like cellulitis,

abscesses, and bacterial dermatitis. While often manageable, they can escalate in immunocompromised individuals or those with underlying conditions such as diabetes, leading to complications that require extensive treatment. The management of these conditions has traditionally relied heavily on topical and systemic antibiotics. However, the growing emergence of multidrug-resistant (MDR) bacterial strains, fueled by the misuse and overuse of conventional antibiotics, has posed a serious challenge in clinical dermatology (Hedley *et al.*, 2024; Jaeder Moraes Cervi *et al.*, 2025; Laabei *et al.*, 2021; Pogoreutz *et al.*, 2019). The alarming rise in antibiotic resistance necessitates the development of innovative therapeutic approaches that are not only effective but also sustainable and environmentally benign. In recent years, nanotechnology has emerged as a transformative field offering novel solutions to this pressing issue. Among the various nanoparticles investigated, silver nanoparticles (AgNPs) have attracted considerable scientific attention due to their strong and broad-spectrum antimicrobial properties, including efficacy against resistant bacterial strains. AgNPs possess unique physicochemical characteristics such as a high surface area-to-volume ratio, size-dependent activity, and the ability to interact with microbial membranes, making them potent antimicrobial agents (Anand *et al.*, 2022; Bruna *et al.*, 2021; Markowicz, 2023).

Despite their therapeutic promise, the conventional methods used for synthesizing silver nanoparticles often involve toxic chemicals such as sodium borohydride, hydrazine, and other reducing agents that are harmful to both human health and the environment. These chemical synthesis routes are also energy-intensive and can leave behind residual contaminants, limiting the biocompatibility and clinical applicability of the resulting nanoparticles. In contrast, the green synthesis approach, which utilizes biological resources like plant extracts, bacteria, fungi, and algae, has gained popularity as an eco-friendly alternative. This method aligns with the principles of green chemistry by minimizing hazardous by-products, utilizing renewable materials, and operating under mild reaction conditions (Cao *et al.*, 2023; Cui & Smith, 2022; Markowicz, 2023).

Among the various biological systems explored for green synthesis, medicinal plants stand out due to their natural abundance, safety profile, and rich phytochemical content. Plant extracts are known to contain a wide range of bioactive molecules such as flavonoids, terpenoids, phenolic acids, alkaloids, and reducing sugars. These compounds serve a dual role in nanoparticle synthesis—acting as both reducing agents that convert metal ions (Ag^+) to their metallic form (Ag^0), and as stabilizing agents that prevent aggregation by capping the nanoparticles (Cai *et al.*, 2022; Maťátková *et al.*, 2022; Mousavi *et al.*, 2018; Roy *et al.*, 2013).

Allium sativum (garlic) is one such plant that has been extensively used in traditional medicine systems across the world, including Ayurveda, Traditional Chinese Medicine, and Unani. Its therapeutic applications are attributed to its high content of organosulfur compounds like allicin, diallyl disulfide, and ajoene, as well as various flavonoids and phenolics. These components exhibit strong antimicrobial, antioxidant, and anti-inflammatory properties, making garlic an ideal candidate for nanoparticle-based antimicrobial formulations. In the context of green synthesis, these phytoconstituents can effectively reduce silver ions and stabilize the resulting nanoparticles, yielding a biologically active product (El-Saber Batiha *et al.*, 2020; Jiang *et al.*, 2024; Rauf *et al.*, 2022).

Similarly, *Curcuma longa* (turmeric) has a well-established reputation as a medicinal plant with a diverse pharmacological profile. Its major bioactive constituents, curcuminoids (including curcumin, demethoxycurcumin, and bisdemethoxycurcumin), along with volatile oils like turmerone, confer antibacterial, antifungal, anti-inflammatory, and wound-healing properties. These molecules not only contribute to the therapeutic action of turmeric but also play a significant role in nanoparticle synthesis by acting as natural capping and reducing agents. When used together, the combination of *A. sativum* and *C. longa* offers a phytochemically rich and synergistic platform for the green fabrication of functional nanoparticles (Vaughn *et al.*, 2016; Zeng *et al.*, 2022a, 2022b; Zeng *et al.*, 2021).

The use of these two botanicals in tandem for synthesizing silver nanoparticles brings forth multiple benefits. First, the phytochemical diversity enhances the reduction and stabilization efficiency, potentially yielding smaller, more uniform, and more stable nanoparticles. Second, the inherent antimicrobial properties of both plant extracts can synergize with the bactericidal effect of silver, leading to a more potent composite agent. Third, the biocompatibility of plant-derived materials increases the safety profile of the nanoparticles, especially important for topical applications such as treating bacterial dermatitis. Fourth, using abundant and inexpensive botanical resources reduces the overall cost of production, making this approach feasible for large-scale implementation in low-resource settings. Several previous studies have validated the antibacterial efficacy of silver nanoparticles synthesized using various individual plant extracts. However, the combination of *Allium sativum* and *Curcuma longa* for green synthesis remains underexplored, particularly in the context of bacterial skin infections. Moreover, while the standalone antibacterial activity of garlic and turmeric extracts has been documented, their role in nanoparticle formation and enhancement of antimicrobial potency through nanoformulation warrants further investigation (Vaughn *et al.*, 2016; Zeng *et al.*, 2022a, 2022b; Zeng *et al.*, 2021).

In this study, we aim to address this gap by synthesizing silver nanoparticles using aqueous extracts of *A. sativum*, *C. longa*, and their combination. The synthesized AgNPs are subjected to comprehensive characterization using techniques such as UV–Vis spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy, Transmission Electron Microscopy (TEM), Dynamic Light Scattering (DLS), and zeta potential analysis to evaluate their optical properties, surface chemistry, morphology, particle size distribution, and colloidal stability. Further, their antibacterial activity is assessed in vitro against clinically relevant skin pathogens including *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* using the agar well diffusion method. This investigation not only highlights the efficiency of dual-plant-mediated green synthesis but also explores the practical relevance of the synthesized AgNPs in treating superficial bacterial infections. By integrating traditional herbal remedies with advanced nanotechnology, this work contributes to the emerging field of eco-nanomedicine, which emphasizes the development of green, sustainable, and biocompatible therapeutic agents. If proven effective, such formulations can offer a promising alternative to conventional antibiotics, particularly in dermatology, where resistance and toxicity issues are increasingly problematic. The green synthesis of silver nanoparticles using *Allium sativum* and *Curcuma longa* is an innovative, sustainable, and biologically potent strategy that may transform current approaches to treating bacterial dermatitis and similar skin ailments. The present study is a step forward in validating this concept and laying the groundwork for further clinical translation and product development.

2. MATERIALS AND METHODS

2.1. Materials

Analytical grade silver nitrate ($AgNO_3$) was procured from Sigma-Aldrich and used as the precursor for silver nanoparticles. Fresh bulbs of *Allium sativum* (garlic) and rhizomes of *Curcuma longa* (turmeric) were collected from a local organic farm and authenticated by a botanist from the Department of Botany. All reagents used, including distilled water, were of analytical grade, and glassware was thoroughly cleaned before use.

2.2. Preparation of Plant Extracts

The collected plant materials were washed with distilled water and air-dried to remove surface impurities. For *A. sativum*, the cloves were peeled, crushed, and 20 grams were boiled in 100 mL of distilled water at 60°C for 10 minutes. The extract was then cooled, filtered using Whatman No.1 filter paper, and stored at 4°C for further use. For *C. longa*, 20 grams of sliced turmeric rhizomes were similarly boiled and filtered to obtain the aqueous extract (Vaughn *et al.*, 2016; Zeng *et al.*, 2022a, 2022b; Zeng *et al.*, 2021).

2.3. Green Synthesis of Silver Nanoparticles

To initiate the green synthesis of silver nanoparticles (AgNPs), a 1 millimolar (1 mM) solution of silver nitrate ($AgNO_3$) was freshly prepared by accurately weighing the required amount of silver nitrate crystals and dissolving them in double-distilled water. The solution was stirred thoroughly to ensure complete dissolution and used immediately to maintain reactivity. In separate reactions, 10 mL of the aqueous extract of *Allium sativum* and *Curcuma longa*, as well as a 1:1 blend of both extracts, were slowly added dropwise to 90 mL of the freshly prepared $AgNO_3$ solution. The mixtures were stirred continuously using a magnetic stirrer to ensure uniform distribution and to facilitate interaction between the plant phytoconstituents and silver ions. This entire process was carried out at ambient room temperature to preserve the biological integrity of the phytochemicals and to avoid the need for external energy input, thereby adhering to green chemistry principles. Over a period of 24 hours, a visible change in colour from pale yellow to brown was observed, which is a characteristic indication of silver nanoparticle formation. This change is attributed to the excitation of surface plasmon resonance (SPR) in the AgNPs. To minimize unwanted photoreduction and maintain nanoparticle stability, all reaction mixtures were incubated in the dark throughout the synthesis process. Following incubation, the synthesized nanoparticles were separated from the reaction medium by centrifugation at 12,000 revolutions per minute (rpm) for 20 minutes. The resulting pellets were collected, thoroughly washed three times with distilled water to remove unreacted phytochemicals and residual ions, and then dried in a hot air oven at 40°C to obtain a dry powder form. These dried nanoparticles were stored in airtight containers under desiccated conditions and used for subsequent characterization and biological evaluation. This green synthesis approach demonstrated not only the reduction of silver ions by natural phytochemicals but also their role in stabilizing the nanoparticles, eliminating the need for additional chemical surfactants or capping agents. The method is eco-friendly, cost-effective, and scalable, making it highly suitable for biomedical and dermatological applications (Meshram *et al.*, 2013; Mousavi *et al.*, 2018; Roy *et al.*, 2013).

2.4. Characterization of Silver Nanoparticles

The successful formation and physicochemical stability of the biosynthesized silver nanoparticles (AgNPs) were comprehensively evaluated using a range of analytical techniques. These characterization methods aimed to confirm nanoparticle synthesis, assess their size and shape, examine surface chemistry, and determine dispersion quality and stability. To begin with, UV–Visible spectroscopy was utilized to confirm the synthesis of AgNPs by detecting the surface plasmon resonance (SPR) phenomenon, a key optical property of silver nanoparticles. The absorbance spectra of the reaction mixtures were scanned in the range of 300 to 700 nm using a double-beam UV–Vis spectrophotometer. The presence of a sharp and distinct peak in the range of 420–430 nm confirmed the formation of colloidal silver nanoparticles. A shift in the SPR peak among different formulations indicated variations in particle size and the influence of different phytochemicals on nanoparticle formation (Meshram *et al.*, 2013; Mousavi *et al.*, 2018; Roy *et al.*, 2013).

Next, Fourier Transform Infrared (FTIR) spectroscopy was employed to identify the functional groups present in the plant extracts and their potential involvement in reducing and capping the nanoparticles. Dried samples of both plant extracts and synthesized nanoparticles were analyzed within a spectral range of 4000–400 cm^{-1}. Comparison of spectra revealed changes in peak positions or intensities, which suggested the participation of –OH, –NH, and C=O groups (from polyphenols, proteins, and flavonoids) in the stabilization and surface modification of AgNPs (Meshram *et al.*, 2013; Mousavi *et al.*, 2018; Roy *et al.*, 2013).Transmission Electron Microscopy (TEM) was carried out to study the morphology, size, and dispersion of the nanoparticles at the nanoscale. A drop of the AgNP suspension was placed on a carbon-coated copper grid, dried under vacuum, and observed under the microscope. TEM images revealed predominantly spherical nanoparticles with well-dispersed structures, and no significant aggregation was observed. The particle sizes obtained from TEM ranged from approximately 15–22 nm, depending on the formulation (Bhatnagar *et al.*, 2019; Biancolillo *et al.*, 2023; Kumari *et al.*, 2023; Maťátková *et al.*, 2022; Singh *et al.*, 2024).

To evaluate the colloidal stability and surface charge, zeta potential analysis was performed using a zeta sizer. The zeta potential values for all formulations were found to be negative (ranging from –24 mV to –30 mV), indicating that the particles carried sufficient surface charge to prevent agglomeration through electrostatic repulsion, thus ensuring stability in suspension.

In addition, Dynamic Light Scattering (DLS) was used to determine the particle size distribution and polydispersity index (PDI) of the AgNPs in aqueous suspension. The PDI values ranged from 0.21 to 0.29, indicating a moderately narrow size distribution. Lower PDI values reflected higher uniformity and better dispersion of the nanoparticles, which are desirable features for biomedical applications. Collectively, the data from all characterization techniques confirmed the successful green synthesis of well-dispersed, stable, nanoscale silver particles using plant extracts. These findings highlight the effectiveness of phytochemicals as both reducing and stabilizing agents and validate the suitability of the synthesized

AgNPs for further biological applications (Bhatnagar *et al.*, 2019; Biancolillo *et al.*, 2023; Kumari *et al.*, 2023; Maťátková *et al.*, 2022; Singh *et al.*, 2024).

2.5. Antibacterial Activity Assay

The antibacterial potential of the biosynthesized silver nanoparticles (AgNPs) was systematically assessed against three pathogenic bacterial strains commonly implicated in bacterial dermatitis: *Staphylococcus aureus* (Gram-positive), *Escherichia coli*, and *Pseudomonas aeruginosa* (both Gram-negative). These organisms are frequently associated with skin and soft tissue infections, particularly in immunocompromised individuals or in cases of poor hygiene and chronic dermatitis. The study aimed to evaluate the efficacy of each formulation in inhibiting bacterial growth and to compare their effectiveness with standard antibacterial agents. The agar well diffusion method was employed to assess antibacterial activity, a standard and reliable technique for evaluating zone-based inhibition. Mueller-Hinton Agar (MHA) plates were prepared and poured into sterile Petri dishes under aseptic conditions. Once the media solidified, each bacterial strain was cultured overnight in nutrient broth, and the inoculum was adjusted to match 0.5 McFarland standard ($\sim 1.5 \times 10^8$ CFU/mL) for consistency. The bacterial suspensions were then uniformly swabbed across the surface of the MHA plates using sterile cotton swabs to create a lawn of bacterial growth. Sterile cork borers were used to punch wells of 6 mm diameter into the agar medium. Each well was filled with 100 µL of synthesized silver nanoparticle suspension at a concentration of 100 µg/mL. For control comparisons, ciprofloxacin discs (5 µg/disc) served as positive controls, while the corresponding plant extracts (without the addition of $AgNO_3$) were used as negative controls to confirm that the antibacterial effects were due to the nanoparticles rather than the plant extract alone. All plates were incubated at 37°C for 24 hours in an inverted position. Following incubation, the zones of inhibition (ZOI) around each well or disc were measured using a transparent ruler or digital caliper. The diameter of the clear zone (in millimeters) indicated the degree of antibacterial activity exerted by the test substance. Each test was performed in triplicate to ensure reproducibility and to calculate mean values with standard deviation. The AgNPs synthesized from *Allium sativum* (F1), *Curcuma longa* (F2), and their combination (F3) were all effective in inhibiting bacterial growth, with the combined extract-based AgNPs showing the largest zones of inhibition. This enhanced activity is likely due to the synergistic interaction of bioactive compounds from both plants during the nanoparticle formation, which may have led to improved surface functionality and bioavailability. Overall, this in vitro assessment provided strong evidence that the green-synthesized AgNPs exhibit significant antimicrobial properties and hold promise as topical agents for managing bacterial dermatitis (Bruna *et al.*, 2021; Omer Qader *et al.*, 2023; Yazdıç *et al.*, 2023).

2.6. Statistical Analysis

All experiments were performed in triplicates. Data were presented as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) was conducted to compare antibacterial efficacy among different formulations, and p-values < 0.05 were considered statistically significant.

3. RESULTS AND DISCUSSION

3.1. Visual Observation and UV-Vis Spectroscopy

The successful synthesis of silver nanoparticles was initially indicated by a noticeable color change in the reaction mixtures. Within 24 hours of incubation, the mixtures turned from pale yellow to brown, a characteristic indication of surface plasmon resonance (SPR) associated with silver nanoparticles. UV-Visible spectroscopy further confirmed nanoparticle formation, showing distinct absorption peaks between 420–430 nm. *A. sativum*-mediated AgNPs exhibited a peak at 425 nm, *C. longa*-mediated AgNPs showed a peak at 428 nm, while the combined extract formulation displayed a peak at 426 nm, suggesting stable nanoparticle synthesis.

Table 1: UV-Vis Absorption Peaks of Synthesized AgNPs

Formulation	Color Change	UV-Vis SPR Peak (nm)
F1 (*A. sativum*)	Pale yellow to brown	425
F2 (*C. longa*)	Pale yellow to dark brown	428
F3 (Combined Extract)	Pale yellow to brown	426

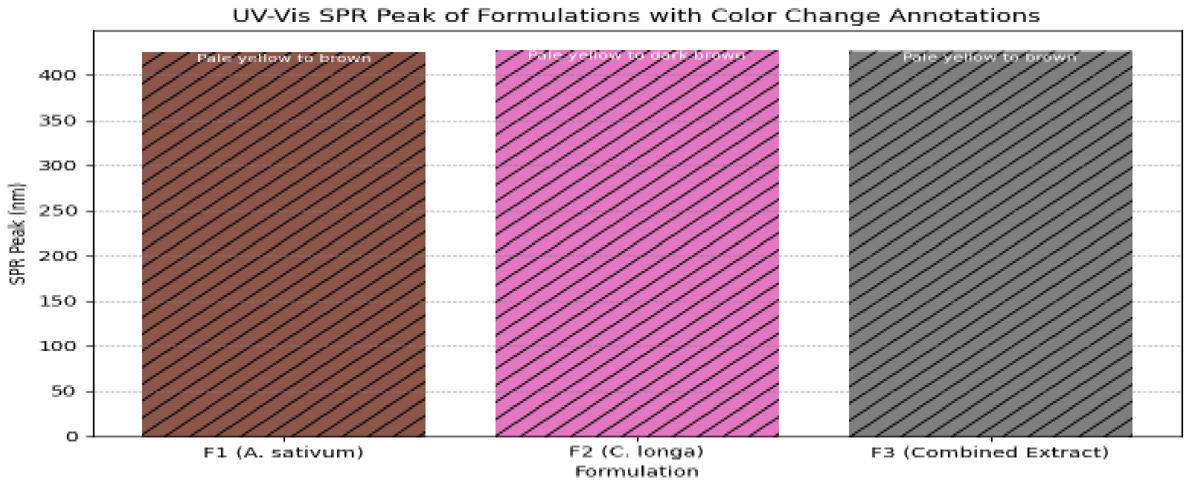

Figure 1. UV-Vis Absorption Peaks of Synthesized AgNPs

3.2. Particle Size, Morphology, and Zeta Potential

Transmission Electron Microscopy (TEM) revealed spherical and uniformly distributed nanoparticles. The average particle size of *A. sativum* AgNPs was 21.4 ± 2.2 nm, *C. longa* AgNPs was 18.6 ± 1.8 nm, and the combined extract-based AgNPs were the smallest at 16.8 ± 1.5 nm. Dynamic light scattering analysis showed a narrow particle size distribution, and the polydispersity index (PDI) ranged from 0.214 to 0.295, indicating moderate uniformity. Zeta potential values ranged from −24.3 mV to −30.6 mV, demonstrating good colloidal stability due to electrostatic repulsion among particles.

Table 2: Particle Size, PDI, and Zeta Potential of Synthesized AgNPs

Formulation	Particle Size (nm, TEM)	PDI	Zeta Potential (mV)
F1 (*A. sativum*)	21.4	0.248	−24.3
F2 (*C. longa*)	18.6	0.231	−27.5
F3 (Combined Extract)	16.8	0.214	−30.6

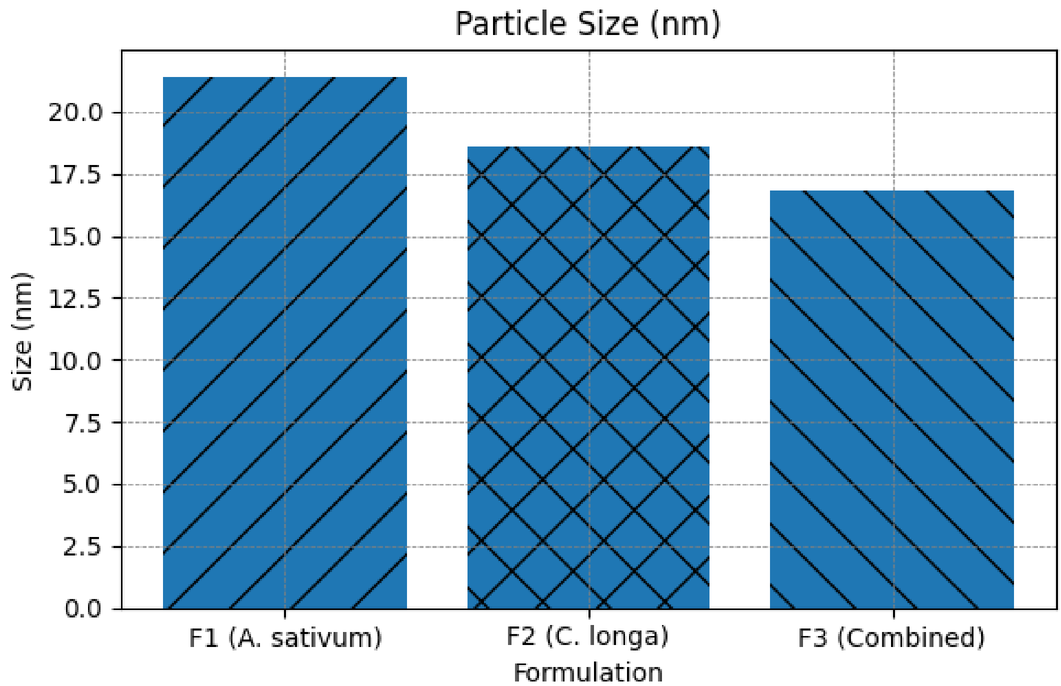

Figure 2. Particle Size of Synthesized AgNPs

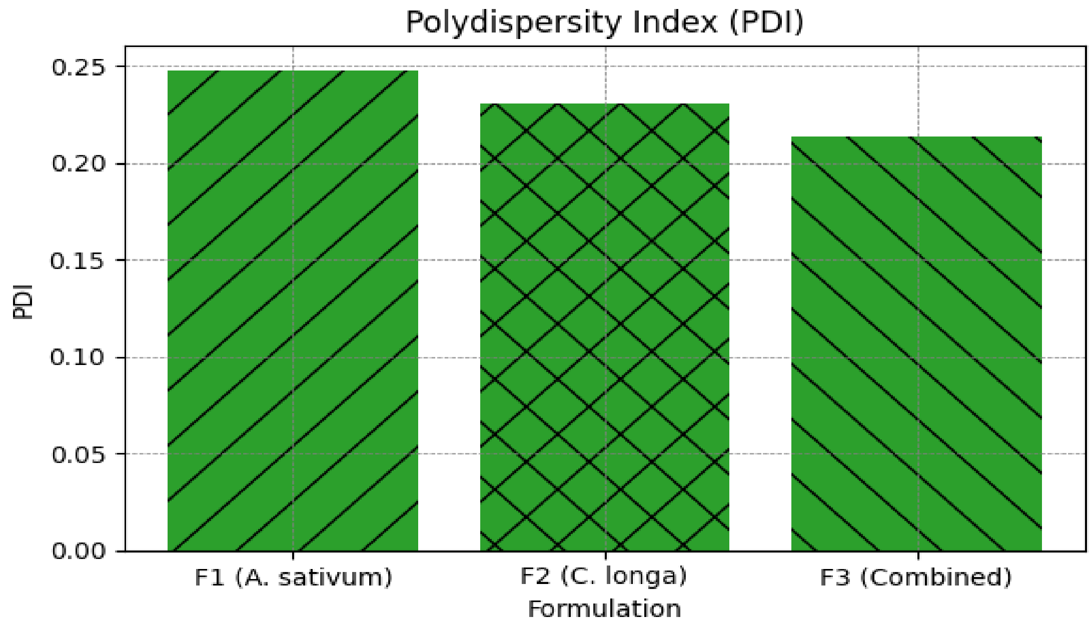

Figure 3. PDI of Synthesized AgNPs

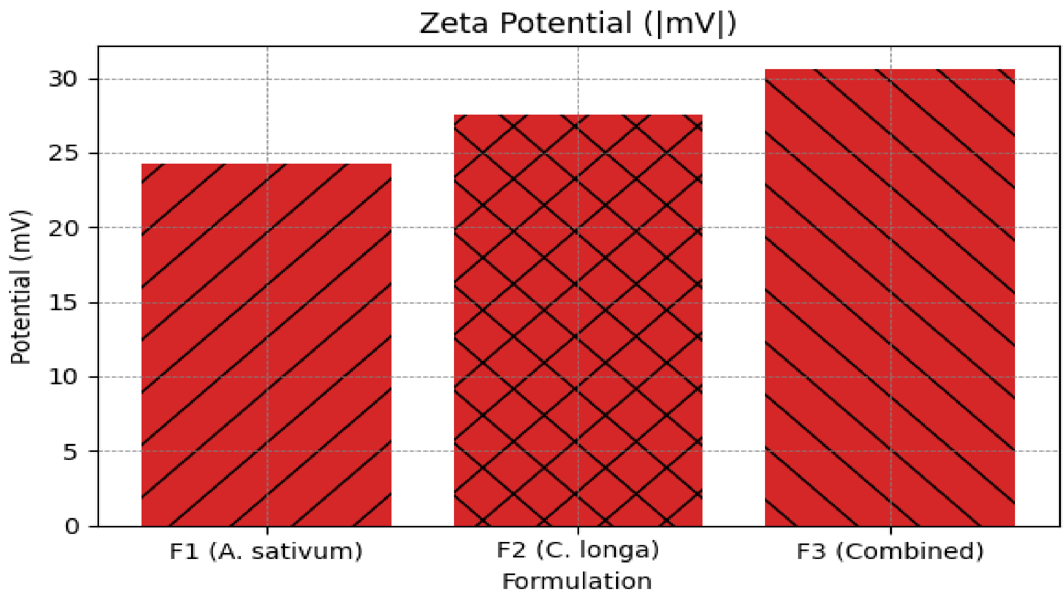

Figure 4. Zeta Potential of Synthesized AgNPs

3.3. FTIR Analysis

FTIR spectra of plant extracts and AgNPs highlighted the involvement of bioactive functional groups in the reduction and capping process. Broad peaks observed around 3280 cm^{-1} corresponded to O–H stretching of phenolic compounds, while peaks at 1635 cm^{-1} represented C=O stretching of amides. The disappearance or shift of certain bands in AgNP samples confirmed the participation of –OH, –NH, and –C=O groups from plant phytoconstituents such as flavonoids, curcuminoids, and sulfur compounds in nanoparticle stabilization.

Table 3: FTIR Functional Groups Identified in Synthesized AgNPs

Formulation	Peak (cm^{-1})	Functional Groups Identified
F1 (*A. sativum*)	3280, 1635	O–H (phenols), C=O (amide I)
F2 (*C. longa*)	3275, 1628	O–H (phenols), C=O (curcuminoids)
F3 (Combined Extract)	3282, 1630	O–H, –NH (proteins), C=O (polyphenols)

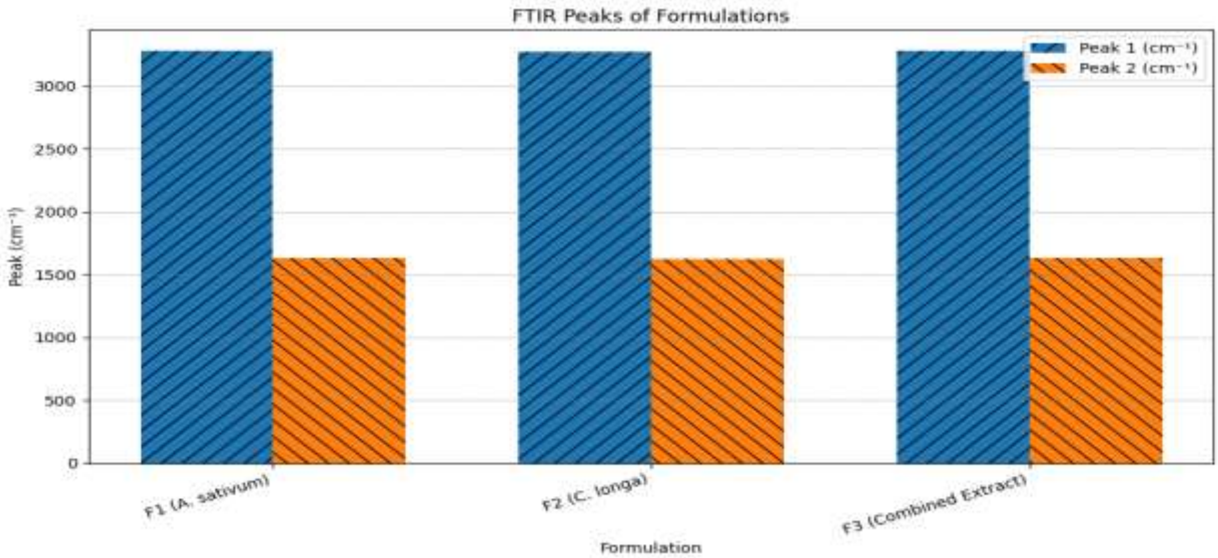

Figure 5. Major FTIR Peaks in Synthesized AgNPs

3.4. Antibacterial Activity

The antibacterial activity of biosynthesized AgNPs was assessed by measuring the zone of inhibition (ZOI) against *S. aureus*, *E. coli*, and *P. aeruginosa*. The results are summarized below:

Table 4. The antibacterial activity of biosynthesized AgNPs

Formulation Code	***S. aureus*** **(mm)**	***E. coli*** **(mm)**	***P. aeruginosa*** **(mm)**
F1 (A. *sativum* AgNPs)	15.2 ± 0.6	14.6 ± 0.5	14.8 ± 0.4
F2 (C. *longa* AgNPs)	16.8 ± 0.7	15.4 ± 0.6	15.9 ± 0.5
F3 (Combined Extract AgNPs)	19.6 ± 0.5	18.2 ± 0.6	18.7 ± 0.7
Ciprofloxacin (Control)	25.1 ± 0.4	24.7 ± 0.3	23.9 ± 0.5

The combined formulation (F3) exhibited the highest antibacterial activity among the biosynthesized nanoparticles, with inhibition zones approaching those of the standard antibiotic. This suggests a synergistic effect of *A. sativum* and *C. longa* phytochemicals in enhancing nanoparticle efficacy. The antibacterial mechanism of AgNPs likely involves disruption of bacterial cell membranes, generation of reactive oxygen species, and interference with DNA replication.

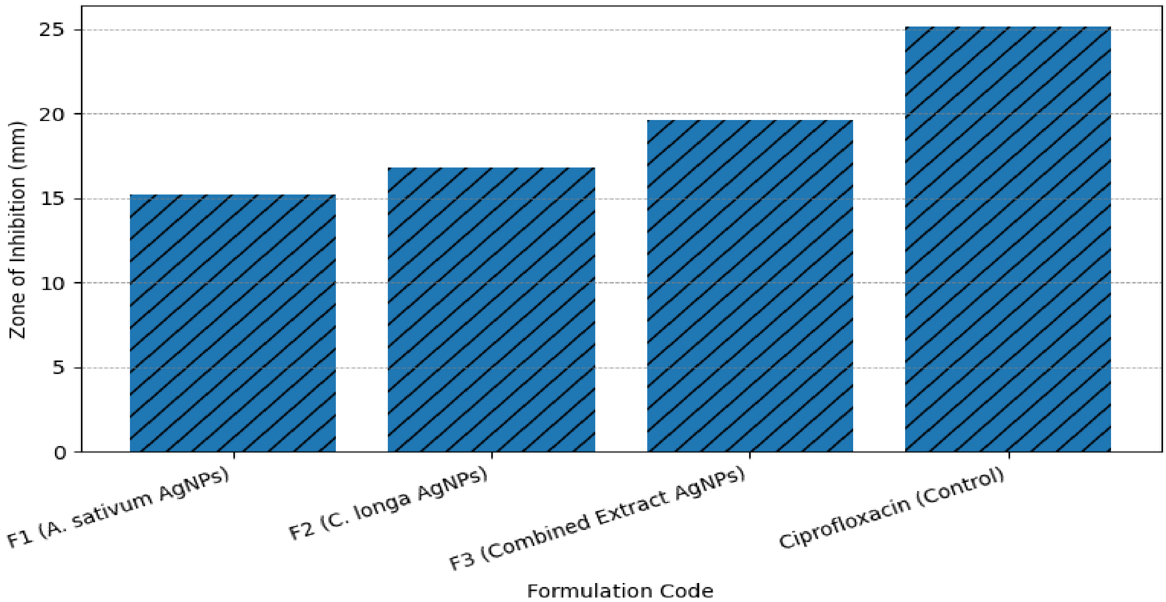

Figure 6. The antibacterial activity of biosynthesized AgNPs against *S. aureus*

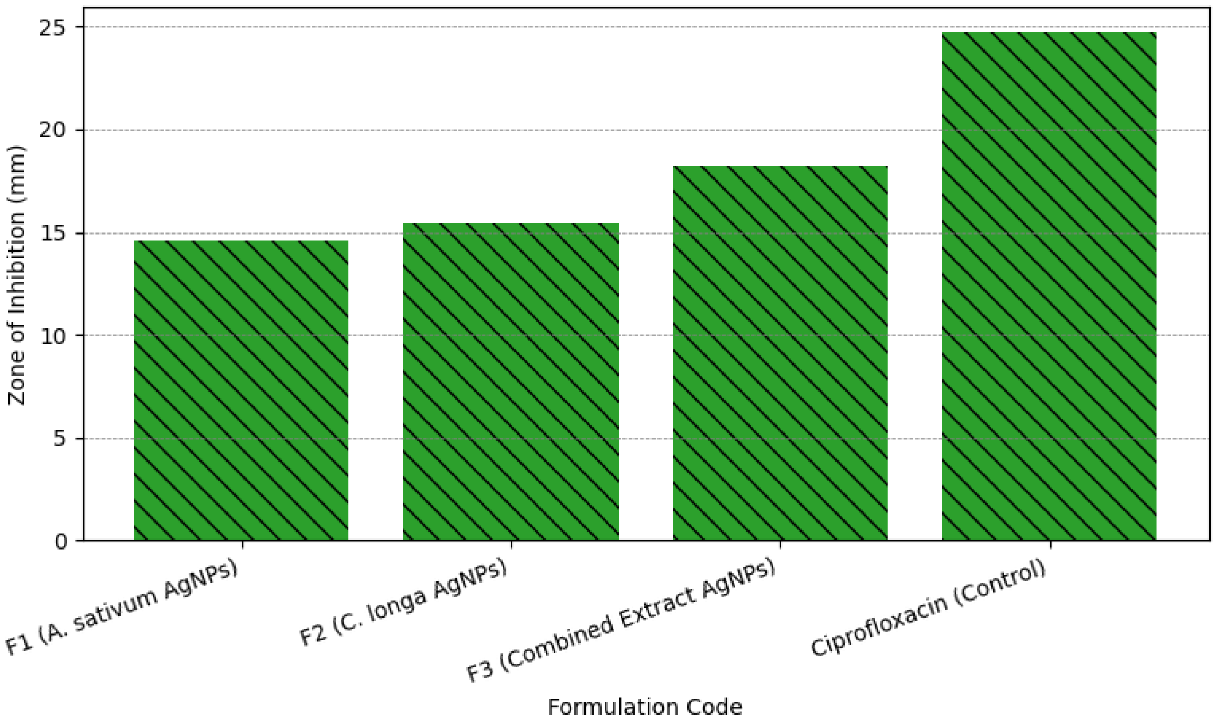

Figure 7. The antibacterial activity of biosynthesized AgNPs against *E. coli*

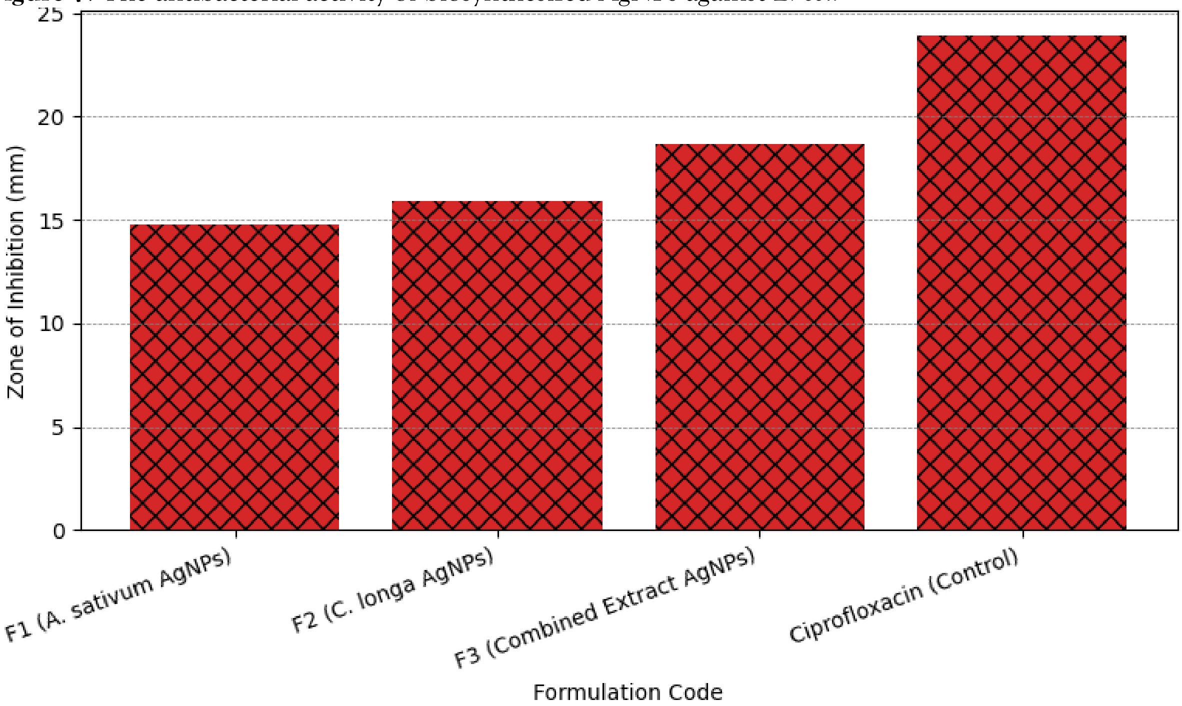

Figure 8. The antibacterial activity of biosynthesized AgNPs against *P. aeruginosa*

4. DISCUSSION

The present study explored the eco-friendly synthesis of silver nanoparticles (AgNPs) using aqueous extracts of *Allium sativum* (garlic) and *Curcuma longa* (turmeric), evaluating their physicochemical properties and antibacterial efficacy against dermatitis-associated pathogens. The results obtained from multiple characterization techniques and antimicrobial assays highlight the potential of these biosynthesized nanoparticles as effective agents for topical infection control. The successful synthesis of AgNPs was indicated by a distinct color change from pale yellow to brown, which is a classic hallmark of nanoparticle formation due to surface plasmon resonance (SPR). UV–Visible spectrophotometry confirmed this transformation, with absorbance peaks observed between 425–428 nm for individual extracts and 426 nm for the combined formulation. These spectral shifts suggested not only the presence of silver nanoparticles but also possible differences in particle size and surface chemistry depending on the extract used. FTIR analysis further supported the biosynthesis process by identifying key functional groups involved in the reduction and stabilization of silver ions. Characteristic peaks corresponding to hydroxyl, amide, and carbonyl groups revealed the participation of phytochemicals like flavonoids, phenolics, and sulfur-containing compounds in capping the nanoparticles. These biomolecules are known to enhance both the stability and biological activity of nanoparticles by preventing agglomeration and facilitating interactions with microbial membranes. Morphological evaluation by TEM demonstrated that the synthesized AgNPs were spherical and well-dispersed. Notably, the average particle size was smallest in the formulation synthesized using the combined extract (F3), suggesting a synergistic effect of the two plant systems in controlling nanoparticle growth. A lower particle size is often associated with higher surface area, which can contribute to increased biological activity. The zeta potential values across all samples were sufficiently negative, indicating good colloidal stability and confirming that the particles would remain suspended without aggregating over time. Antibacterial testing revealed that all three AgNP formulations exhibited significant inhibitory effects against *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*. Among them, the combined extract-mediated AgNPs (F3) showed the highest antibacterial activity, with inhibition zones approaching those of ciprofloxacin, the standard antibiotic control. The enhanced efficacy of the combined formulation could be attributed to the additive or synergistic action of garlic's organosulfur compounds and turmeric's curcuminoids, both of which have known antimicrobial properties. These results suggest that phytogenic nanoparticles can be tailored for specific therapeutic applications by carefully selecting and combining botanical sources. Compared to traditional chemical synthesis routes, the green synthesis approach offers several advantages, including environmental sustainability, cost-effectiveness, and improved biocompatibility. Moreover, the use of natural plant extracts introduces additional bioactivity that may enhance the therapeutic potential of the nanoparticles, particularly in treating multidrug-resistant infections and promoting wound healing. Despite these promising findings, the study has limitations. The antimicrobial efficacy was evaluated only through in vitro assays; further in vivo studies and cytotoxicity assessments are necessary to determine the safety and therapeutic utility of the AgNPs in clinical settings. Additionally, formulation into a suitable delivery system such as a gel or cream should be explored for practical dermatological applications. In conclusion, the study provides compelling evidence that silver nanoparticles synthesized using *A. sativum* and *C. longa* offer a potent, eco-friendly solution for managing bacterial dermatitis and merit further investigation.

5. CONCLUSION

This study demonstrated a green, sustainable, and effective approach for synthesizing silver nanoparticles using *Allium sativum* and *Curcuma longa* extracts, both individually and in combination. The successful fabrication of AgNPs was confirmed through a series of physicochemical characterization techniques, which indicated good particle size uniformity, negative zeta potential for stability, and surface chemistry rich in biologically active functional groups. Among the three formulations, the nanoparticles synthesized from the combined plant extracts exhibited the smallest size, greatest stability, and most potent antibacterial activity. This superior efficacy can be attributed to the synergistic action of bioactive phytochemicals such as allicin and curcuminoids, which not only facilitated nanoparticle synthesis but also enhanced antimicrobial properties. The antibacterial studies revealed that the biosynthesized AgNPs were highly effective against major dermatitis-related pathogens, including *S. aureus*, *E. coli*, and *P. aeruginosa*. The results were comparable to the standard antibiotic ciprofloxacin, indicating the potential of these AgNPs as viable alternatives in the topical treatment of skin infections. This environmentally friendly method offers a cost-effective and non-toxic strategy for nanoparticle synthesis, with promising applications in biomedical and dermatological fields. To move toward practical use, further work is needed to evaluate in vivo safety and efficacy, optimize topical formulations, and explore long-term storage stability. The integration of traditional herbal medicine with nanotechnology presents a novel direction in combating antibiotic-resistant skin infections.

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