



Green Synthesis of Silver Nanoparticles Using *Althaea officinalis* and *Pterocarpus santalinus* Formulation and its Anti-inflammatory and Antimicrobial Activity against Oral Wound Pathogen

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ABSTRACT

Green synthesis of silver nanoparticles (AgNPs) using plant-derived bioactive compounds has emerged as an environmentally friendly alternative to conventional chemical synthesis methods. Although several medicinal plants have been explored for nanoparticle synthesis, limited studies have investigated the combined use of *Althaea officinalis* and *Pterocarpus santalinus* extracts for the fabrication of AgNPs and evaluation of their biological activities. The objective of the study is to formulate a novel wound healing gel that can be used for oral wounds such as extraction sockets, surgical incisions, periodontal surgeries, etc. Therefore, the present study aimed to synthesize silver nanoparticles using aqueous extracts of *A. officinalis* and *P. santalinus* and to evaluate their in vitro antimicrobial and anti-inflammatory activities. Plant extracts obtained from Saveetha Dental College and Hospitals were used as reducing and stabilizing agents for the synthesis of AgNPs. Silver nanoparticles were synthesized by reacting the plant extracts with aqueous silver nitrate solution (1 mM concentration) under controlled conditions of temperature, pH, and incubation time. Nanoparticle formation was initially confirmed by UV-Visible spectroscopy, which showed a characteristic surface plasmon resonance peak at 450 nm. Antibacterial activity was evaluated against *Candida albicans*, *Lactobacillus spp.*, *Streptococcus mutans*, and *Staphylococcus aureus* using the agar well diffusion method, and the zones of inhibition were measured in millimeters. The synthesized AgNPs exhibited inhibitory activity against all tested microorganisms, with mean zones of inhibition of 15 mm for *C. albicans*, 17 mm for *Lactobacillus sp.*, 9 mm for *S. mutans*, and 17 mm for *S. aureus*. Anti-inflammatory activity was assessed using bovine serum albumin denaturation, egg albumin denaturation, and membrane stabilization assays. The synthesized AgNPs demonstrated concentration-dependent anti-inflammatory effects, with a maximum inhibition of approximately 75% in protein denaturation assays and 80% membrane stabilization activity. The findings suggest that *A. officinalis* and *P. santalinus*-mediated AgNPs possess in vitro antibacterial and anti-inflammatory properties.

Keywords: Green synthesis; Silver nanoparticles; *Althaea officinalis*; *Pterocarpus santalinus*; Antibacterial activity; Medicine; Biological production; Anti-inflammatory activity; Green consumption.

1. INTRODUCTION

Wound healing gel is intended to fasten the natural healing process of an injury (Wang *et al.* 2018). The gel is made up of *Althaea officinalis* and *Pterocarpus santalinus* along with silver nanoparticles. Antimicrobial substances aid in infection prevention, which is essential to the healing of wounds. They protect the wounded area from dangerous microorganisms so that healing cells can proliferate unhindered (Tonnesen *et al.* 2000). Wound healing gels are renowned for their adaptability to various dental wounds such as extraction sockets and incision wounds. They act as a barrier of defense and encourage moisture, which is thought to create the ideal environment for healing (Bâldea *et al.* 2023). Gel-based drug delivery systems have gained considerable attention in wound management due to their ability to maintain a

moist wound environment, enhance patient compliance, facilitate localized drug delivery, and minimize systemic side effects. Several studies have reported that silver nanoparticle-loaded wound-healing gels exhibit enhanced antibacterial activity, reduced microbial colonization, and improved wound repair compared with conventional formulations. Therefore, integrating green-synthesized silver nanoparticles into a topical gel system may represent a promising strategy for developing advanced wound-care materials with improved therapeutic performance.

Nanotechnology, at the intersection of science and engineering, has revolutionized various industries by manipulating materials at the nanoscale (Mary *et al.* 2023). Among the wide range of nanomaterials, silver nanoparticles (AgNPs) have become a remarkable and

adaptable element (Abbasi *et al.* 2016). The particular physical, chemical, and biological characteristics of silver nanoparticles, which typically range in size from 1 to 100 nanometers (Schmalz *et al.* 2017), set them apart from bulk silver and other nanomaterials. AgNPs are an intriguing research topic because of these characteristics, which are brought on by the high surface area-to-volume ratio, quantum confinement effects, and plasmonic activity (Sabarees *et al.* 2022). Their small size makes it possible for them to interact with various biological and chemical systems more effectively, opening the door for a wide range of cutting-edge applications in multiple industries (Tharani *et al.* 2023).

Silver has been known for its antibacterial capabilities, and the move to the nanoscale has increased its potency even more (Xu *et al.* 2020). AgNPs can successfully fight off a variety of pathogens, such as bacteria, fungi, and viruses, by rupturing their cell membranes, preventing cell development, and interfering with DNA replication (Pandiyani *et al.* 2023). AgNPs are now used in a variety of healthcare goods, such as wound dressings, coatings for medical devices, and even in the fight against diseases that are resistant to antibiotics, as a result of their antibacterial power (Mofazzal *et al.* 2018).

Green synthesis of silver nanoparticles (AgNPs) using plant extracts has emerged as an environmentally friendly and sustainable alternative to conventional physical and chemical synthesis methods, which often require high energy input, expensive equipment, and toxic reagents. Plant-mediated synthesis offers advantages such as cost-effectiveness, biocompatibility, eco-friendliness, and improved nanoparticle stability. The common wound healing microbes in the oral cavity are *Candida albicans*, *Lactobacillus* species, *Staphylococcus aureus*, and *Streptococcus mutans*. The combination of silver nanoparticles along with the herbal counterpart aids in wound healing activity. The combination enhances nanoparticle stability, surface functionality, and overall antimicrobial and anti-inflammatory efficacy compared to the individual components.

The natural defense mechanism includes a complex and important process called wound healing (Xue *et al.* 2023). Many different plants and herbal treatments have been used throughout history to speed the healing of wounds (Mohsenikia *et al.* 2020). The marshmallow plant, formally known as *Althaea officinalis*, is one of these extraordinary plants with powerful wound-healing abilities (Albahri *et al.* 2023). The mucilage content of the marshmallow plant is one of the key elements causing it to have wound healing qualities. Mucilage is a viscous, gel-like compound that exists in the roots, leaves, and flowers of plants. Because arabinogalactans make up the majority of the polysaccharides in this mucilage, they are noted for being calming and anti-inflammatory. When applied topically,

marshmallow extracts create a moisturizing and protective layer over the wound that lessens irritability and speeds up healing (Rezaei *et al.* 2015) (Varshasree *et al.* 2025).

Red sandalwood, a renowned tree that is native to the Indian subcontinent, is one of these botanical wonders that has long held a special position in traditional medicine because of its exceptional wound healing properties (Bulle *et al.* 2016) (Suresh *et al.* 2024). The meaning of its scientific name, *Pterocarpus santalinus*, which translates to "winged fruit of sandalwood," emphasizes its close ties to the prestigious sandalwood tree.

The deep red hue of red sandalwood serves as an indicator of its rich reservoir of bioactive compounds. Santalin and pterostilbene are two essential components that support the plant's exceptional wound healing properties (Dahat *et al.* 2021). These substances have a variety of qualities, such as anti-inflammatory, antibacterial, and antioxidant, which are crucial for speeding up the wound healing (Biswas *et al.* 2004).

The anti-inflammatory qualities of red sandalwood are essential in resolving the problem since they reduce swelling, redness, and discomfort near the lesion (Abedi *et al.* 2020). Red sandalwood prepares the ground for the quick start of healing by reducing the inflammatory reaction (Biswas *et al.* 2004). Free radicals can cause oxidative stress, which can hinder wound healing by causing further damage to the wounded tissue (Anmol *et al.* 2024). Due to the abundance of antioxidants in red sandalwood, these dangerous free radicals are neutralized, protecting the wound from oxidative stress and promoting tissue integrity (Akhouri *et al.* 2020). It is a crucial ally in the process of wound management because of its ability to reduce inflammation, fight oxidative stress, promote cell proliferation, and increase the production of collagen (Biswas *et al.* 2004). The aim and objective of the present study is to assess the anti-microbial and anti-inflammatory activity of *A.officinalis* and *P.santalinus* along with silver nanoparticles.

2. MATERIALS AND METHODS

2.1 Preparation of *A. officinalis* and *P. santalinus* Extracts

The plant extracts were sourced from Saveetha Dental College and Hospital in powdered form obtained from the root of the plants. 1 gram of each extract is taken and boiled with 100 ml of distilled water in 50-60 °C for 60 minutes under constant stirring. The extracts were prepared in a combined formulation. After boiling, the solution was then filtered using a nylon mesh cloth and stored at 4 °C for the nanoparticle synthesis.

2.2 Synthesis of Silver Nanoparticles using *A. officinalis* and *P. santalinus* Extracts

For silver nanoparticle synthesis, 20 ml of the plant extract was added to 90 ml aqueous solution of AgNO₃ (1 mM) (AgNO₃ purchased from Himedia Laboratories, India) and placed at room temperature. The color change from bright red to dark brown was noted, indicating that silver nanoparticles had formed. A control is maintained without the addition of the plant extract to the silver particles, which shows no color change.

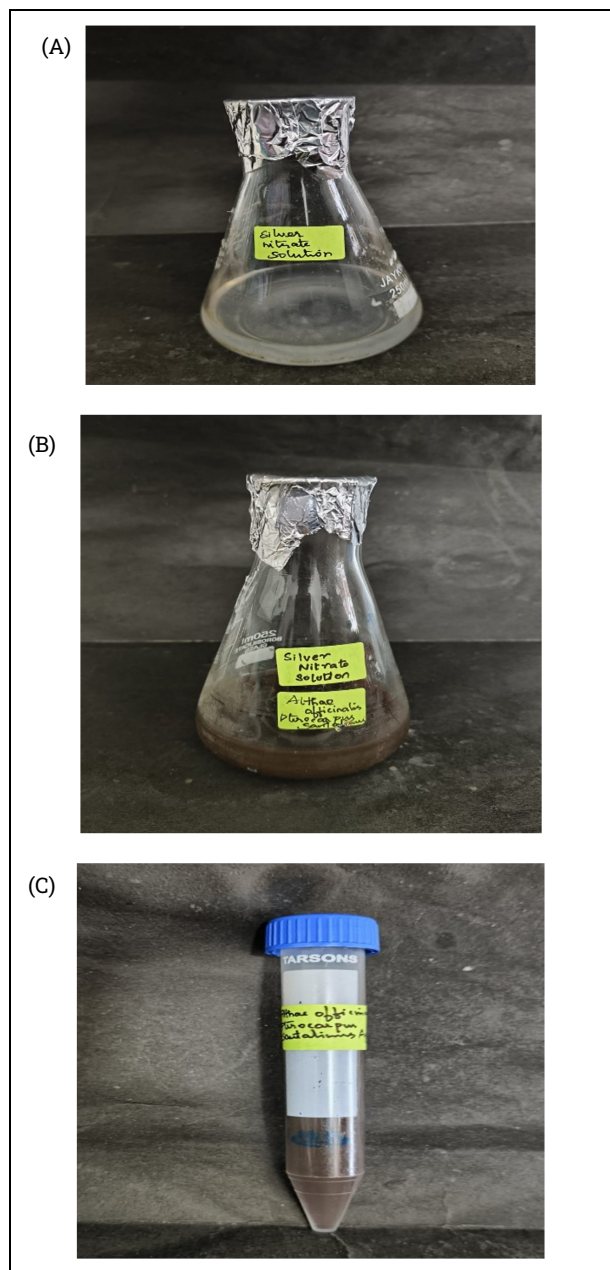


Fig. 1: (A) Silver nitrate solution (B) Reaction mixture containing silver nitrate solution and extracts of *A. officinalis* and *P. santalinus* and (C) Wound healing gel-*A. officinalis* and *P. santalinus* formulation with silver nanoparticles

2.3 Characterization Studies

The formation is monitored through UV-vis spectra in a wavelength range of 300-800nm (Aqueous silver nitrate solution with *A. officinalis* and *P. santalinus* extract in a conical flask). The UV-vis spectra readings are carried out on a Perkin-Elmer double-beam spectrophotometer operated with a resolution of 2nm. The reaction mixture is centrifuged for 10 mins at 10,000 rpm for 10 minutes at 4 °C and then washed with 10ml double distilled water. The centrifugation process is repeated 4-5 times, and the pellet is dried in a hot air oven. The dried powder is saved for future studies.

2.4 Identification of Oral Wound Pathogens

S. aureus, *S. mutans*, *C. albicans* and Lactobacillus were isolated in nutrient agar plates. The extract was collected from *A. officinalis* and *P. santalinus*, and the diluted extract was added serially as a positive control. 0.1 ml of the diluted extract was placed on the nutrient agar plates. The plates were incubated at 37° C for 24 hours.

2.5 Assessment of Antimicrobial Activity of Green-synthesized Silver Nanoparticles

Using the agar well diffusion method, the antimicrobial activity of the green-synthesized silver nanoparticles was assessed. Mueller Hinton agar plates were made and autoclaved for 15–20 minutes at 121°C to sterilize them. The medium was put onto sterile Petri plates, and it was then left to cool to room temperature (30 degree Celsius). Using sterile cotton swabs, the bacterial suspension (*Streptococcus mutans*, *Lactobacillus sp.*, *Staphylococcus aureus*, and *Candida albicans*) was equally distributed onto the agar plates. In the agar plates, wells of 9 mm in diameter were made using a sterile polystyrene tip. Next, varying amounts of Ag NPs (25 µg, 50 µg, and 100 µg) were added to the wells. As a standard, an antibiotic (such as Fungi-Fluconazole, 200mg or Bacteria-Amox, 250mg) was employed. For 24 hours and 48 hours, respectively, the plates were incubated at 37°C for the growth of fungi. By measuring the diameter of the inhibitory zone surrounding the wells, the antibacterial activity was assessed. A ruler was used to measure the zone of inhibition's diameter in millimeters (mm), and the value of the zone of inhibition was computed.

2.6 Assessment of Anti-inflammatory Activity of Green-synthesized Silver Nanoparticles

2.6.1 Bovine Serum Albumin Denaturation Assay

Green synthesized nanoparticles are tested for anti-inflammatory activity using the Bovine and Egg albumin denaturation assay. 0.45mL of bovine serum albumin was mixed with 0.05 mL of different

concentrations (10-50 µg/mL) of *A. officinalis*, and *P. santalinus* mediated silver nanoparticles. The pH maintained was 6.3. Then it was placed at room temperature for 10 minutes, followed by water bath incubation at 55°C for 30 min. Diclofenac sodium was used as a standard group, while dimethyl sulphoxide was used as a control. Then, the samples were measured spectrophotometrically at 660nm (Precupas *et al.* 2016).

The percentage of protein denaturation was determined utilizing the following equation:

$$\% \text{ inhibition} = \frac{\text{Absorbance of control} - \text{Absorbance of sample} \times 100}{\text{Absorbance of control}}$$

2.6.2 Egg Albumin Denaturation Assay

To perform the Egg albumin denaturation assay, 0.2mL of fresh egg albumin was mixed with 2.8 mL of phosphate buffer. Different concentrations (10-50 µg/mL) of *A. officinalis* and *P. santalinus* mediated silver nanoparticles were added to the reaction mixture. The pH maintained was 6.3. Then it was placed at room temperature for 10 minutes, followed by water bath incubation at 55°C for 30 min. Diclofenac sodium was used as a standard group, while dimethyl sulphoxide was used as a control. Then, the samples were measured spectrophotometrically at 660nm.

The percentage of protein denaturation was determined utilizing the following equation:

$$\% \text{ inhibition} = \frac{\text{Absorbance of control} - \text{Absorbance of sample} \times 100}{\text{Absorbance of control}}$$

2.6.3 Membrane Stabilization Assay

The in vitro membrane stabilization assay is a widely used technique for evaluating the properties of membrane stabilization of natural and synthetic compounds. This assay measures the ability of a compound to stabilize the cell membrane by preventing its discontinuity and subsequent release of intracellular contents. The materials include Phosphate-buffered saline (PBS), Tris-HCl buffer (50 mM, pH 7.4), and different concentrations of silver nanoparticles (10-50 µg/mL), Centrifuge tube, and a UV-Vis spectrophotometer.

2.6.4 Assay Procedure

1mL of the RBC suspension was pipetted into each centrifuge tube. Then, different concentrations of silver nanoparticles were added to the tubes. Mix gently and incubate the tubes at 37°C for 30 minutes. Centrifuge the tubes at 1000g for 10 minutes at room temperature to pellet the RBCs. Using a UV-Vis spectrophotometer, the absorbance of the supernatant was measured at 540 nm.

Calculate the percentage inhibition of hemolysis using the following formula:

$$\% \text{ inhibition} = \frac{(\text{OD control} - \text{OD sample})}{\text{OD control}} \times 100$$

where the OD control is the RBC suspension absorption without the test compound(s), and the OD sample is the RBC suspension absorption with the test compound (Liu *et al.* 2010).

3. RESULTS

3.1 UV-spectroscopy Analysis

Figure 6 shows UV-vis spectra of the reaction mixture of silver nanoparticles with *A. officinalis* and *P. santalinus*, exposed at different time intervals such as 10min, 30min, 1h, 1.5h, 2h, 2.5h, 3h, and 3.5h. When scanned at a range of 300-800nm, the surface plasmon resonance peak is observed at 450 nm, which denotes the presence of silver nanoparticles mediated by *A. officinalis* and *P. santalinus*. The peak raised is due to the effect of SPR on the synthesized metallic nanoparticles. The UV-vis spectrum signifies that the absorbance of silver nanoparticles gradually increases from 1.5h to 3h, and the reaction has ended at 3h. In the green-mediated synthesis, the color intensity increases with increasing duration of incubation. Nucleation of silver metal ions occurs between 1.5h and 3h. In green synthesis, the 24h absorption band confirms that the silver nanoparticle synthesis was completed within 3h of incubation.

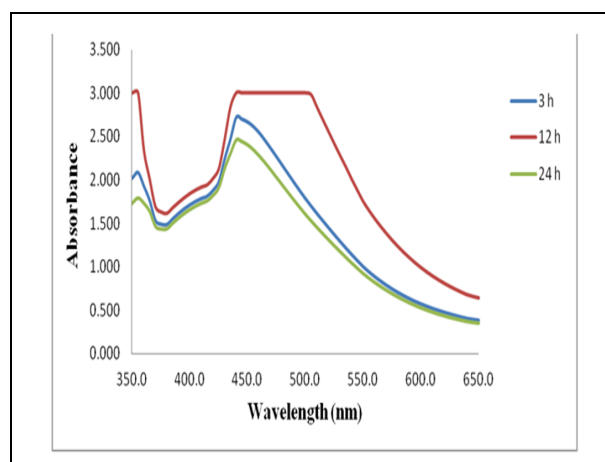


Fig. 2: UV-Visible spectroscopy analysis of silver nanoparticles

3.2 Antimicrobial Activity

The antibacterial activity is examined by using a well diffusion method under in vitro conditions against *C. albicans*, *Lactobacillus*, *S. mutans* and *S. aureus*. The study focuses on oral wounds, and oral microorganisms were identified for the study. The silver nanoparticle combined wound healing gel exhibits an admirable zone of inhibition at 50µL and 100 µL against *C. albicans*, *Lactobacillus*, *S. mutans* and *S. aureus*. The maximum zone of inhibition against *C. albicans* is 26mm, against *Lactobacillus* is 46mm, against *S. mutans* is 34mm and

against *S. aureus* is 32mm. The silver nanoparticles combined with plant extracts show a fine zone of inhibition when compared to nanoparticles and plant extracts. This clearly indicates that the green-synthesized silver nanoparticles are great antibacterial agents against the oral pathogens employed. When compared to silver nanoparticles, the green-synthesized silver nanoparticles show an enhanced zone of inhibition against oral pathogens. The product is a good source of antimicrobial agents that can be extensively useful in biomedical applications.

Table 1: Antimicrobial activity of *A. officinalis* and *P. santalinus* mediated silver nanoparticles

Organisms	25 µg/mL	50 µg/mL	100 µg/mL	Commercial Wound Healing Gel
<i>C. albicans</i>	16	21	26	15
<i>Lactobacillus</i> spp.	35	42	46	17
<i>S. mutans</i>	26	30	34	9
<i>S. aureus</i>	25	30	32	17

3.3 Anti-inflammatory Activity

Bovine serum albumin assay shows inhibition starting from 40% to 75%. There is a gradual increase in the zone of inhibition starting from concentrations 10µL, 20µL, 30µL, 40µL and 50µL. The peak in the zone of inhibition is observed at 50µL.

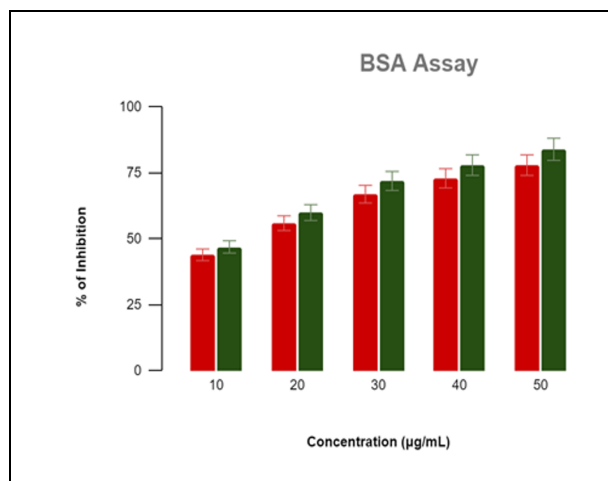


Fig. 3: Anti-inflammatory activity of *A. officinalis* and *P. santalinus* mediated silver nanoparticles (Bovine serum albumin denaturation assay)

Egg albumin denaturation assay shows inhibition starting from 50% to 75%. There is a gradual increase in the zone of inhibition starting from concentrations 10µL, 20µL, 30µL, 40µL and 50µL. The peak in the zone of inhibition is observed at 50µL.

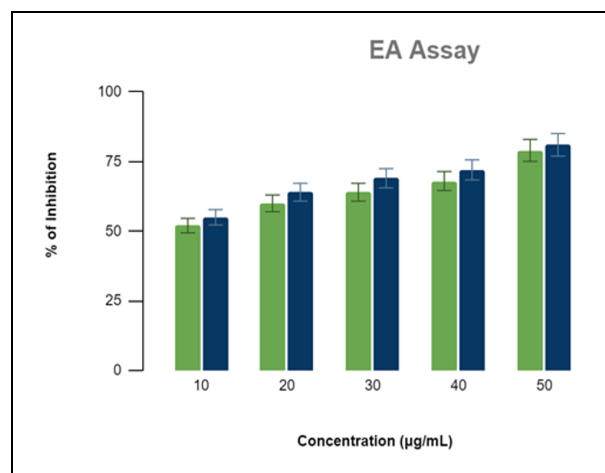


Fig. 4: Anti-inflammatory activity of *A. officinalis* and *P. santalinus* mediated silver nanoparticles (Egg albumin denaturation assay)

The membrane stabilization assay shows inhibition starting from 55% to 80%. There is a gradual increase in the zone of inhibition starting from concentrations 10µL, 20µL, 30µL, 40µL, and 50µL. The peak in the zone of inhibition is observed at 50µL.

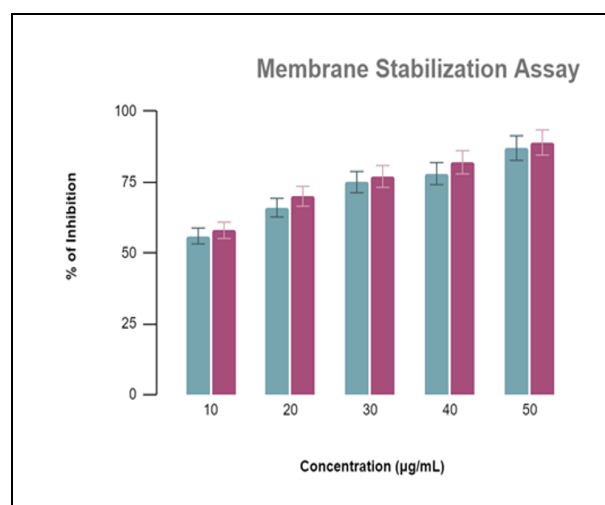


Fig. 5: Anti-inflammatory activity of *A. officinalis* and *P. santalinus* mediated silver nanoparticles (Membrane stabilization assay)

4. DISCUSSION

The present study demonstrated the successful green synthesis of silver nanoparticles (AgNPs) using *Althae officinalis* and *Pterocarpus santalinus* extracts, with subsequent evaluation of their antimicrobial and anti-inflammatory properties. The synthesis process was monitored using UV-Visible spectroscopy, which revealed a characteristic surface plasmon resonance (SPR) band at approximately 450 nm. This absorption peak is a distinctive optical feature of AgNPs and confirms the reduction of silver ions into metallic

nanoparticles by the phytochemicals present in the plant extracts. Polyphenols, flavonoids, tannins, and other bioactive compounds are known to act as both reducing and stabilizing agents during green synthesis, facilitating nanoparticle formation while preventing excessive aggregation.

The gradual increase in absorbance observed between 1.5 h and 3 h indicates the active nucleation and growth phase of nanoparticle synthesis. During this period, silver ions are continuously reduced, resulting in the formation of a larger number of nanoparticles and consequently a stronger SPR signal. The stabilization of the absorption band after 3 h suggests that the reduction process had reached completion, indicating exhaustion of the available silver ions or attainment of reaction equilibrium. Similar observations have been reported in plant-mediated synthesis studies, where completion of nanoparticle formation is generally accompanied by stabilization of the SPR intensity. The increase in colour intensity with incubation time further supports the progressive formation of AgNPs, as the brown coloration is directly associated with collective oscillation of conduction electrons on the nanoparticle surface.

The comparative UV–Visible analysis performed at extended incubation periods demonstrated that the 12 h sample exhibited the highest absorbance intensity and a relatively sharper SPR peak compared with the 3 h and 24 h samples. Peak sharpness is often associated with greater particle uniformity and a narrower size distribution, suggesting that nanoparticles formed at 12 h possessed improved homogeneity. In contrast, the broader peaks observed at 3 h and 24 h indicate increased polydispersity and the presence of particles with varying dimensions. Peak broadening in UV–Visible spectra is commonly attributed to differences in particle size, shape, and interparticle interactions. The absence of a substantial shift in SPR wavelength across different incubation periods indicates that the synthesized nanoparticles remained stable and experienced minimal aggregation. Although a slight reduction in absorbance was observed at 24 h, this may be attributed to limited particle growth, sedimentation, or minor aggregation resulting from prolonged incubation. Nevertheless, the maintained SPR position suggests that the capping molecules derived from *A. officinalis* and *P. santalinus* effectively stabilized the nanoparticles. Based on these observations, the synthesis process appears to achieve optimal nanoparticle formation within 12 h, producing particles with enhanced uniformity and colloidal stability.

The antimicrobial assessment revealed significant inhibitory activity of the synthesized AgNPs against *Candida albicans*, *Lactobacillus spp.*, *Streptococcus mutans*, and *Staphylococcus aureus*. The antimicrobial effect increased in a concentration-dependent manner, with the highest inhibition observed

at 100 µg/mL. Notably, *Lactobacillus spp.* exhibited the greatest susceptibility, followed by *S. mutans*, *S. aureus*, and *C. albicans*. The superior antimicrobial efficacy of the green-synthesized nanoparticles compared with the commercial wound-healing gel highlights the therapeutic potential of the nanoparticle formulation. The enhanced antimicrobial activity may result from the synergistic interaction between silver nanoparticles and phytoconstituents present in the plant extracts. Silver nanoparticles exert their antimicrobial action through multiple mechanisms, including disruption of microbial cell membranes, generation of reactive oxygen species, interference with DNA replication, inhibition of respiratory enzymes, and alteration of membrane permeability. The nanoscale dimensions of AgNPs provide a large surface area-to-volume ratio, enabling greater interaction with microbial cells and facilitating penetration into intracellular compartments. Such multifaceted mechanisms reduce the likelihood of microbial resistance development and contribute to broad-spectrum antimicrobial activity.

The notable inhibition observed against *S. mutans* and *S. aureus* is particularly relevant to oral health applications, as these microorganisms are implicated in dental caries, biofilm formation, and oral infections. Likewise, inhibition of *C. albicans* suggests potential utility in controlling opportunistic fungal infections within the oral cavity. The broad-spectrum activity demonstrated in this study supports the use of plant-mediated AgNPs as promising antimicrobial agents for dental and biomedical applications.

The anti-inflammatory potential of the synthesized nanoparticles was confirmed using bovine serum albumin denaturation, egg albumin denaturation, and membrane stabilization assays. All three assays demonstrated concentration-dependent inhibition, with maximum activity observed at 50 µL. Protein denaturation is a well-recognized mechanism associated with inflammatory disorders, and the ability of AgNPs to inhibit albumin denaturation indicates their potential to protect proteins from structural alterations induced by inflammatory mediators. The comparable results obtained from both bovine serum albumin and egg albumin assays suggest consistent anti-inflammatory effects across different protein substrates.

Among the evaluated assays, membrane stabilization exhibited the highest percentage inhibition, indicating a strong capacity of the synthesized nanoparticles to protect cellular membranes against lysis. Stabilization of biological membranes is an important indicator of anti-inflammatory activity because lysosomal membrane rupture during inflammation releases proteolytic enzymes that contribute to tissue damage and perpetuate inflammatory responses. By preserving membrane integrity, AgNPs may limit the release of inflammatory mediators and reduce tissue

injury. The observed anti-inflammatory activity may be attributed to both the intrinsic properties of silver nanoparticles and the bioactive phytochemicals adsorbed onto their surfaces. Phenolic compounds, flavonoids, and tannins present in *A. officinalis* and *P. santalinus* possess well-documented antioxidant and anti-inflammatory properties that may synergistically enhance the biological activity of the nanoparticles.

Collectively, the findings demonstrate that *A. officinalis* and *P. santalinus*-mediated silver nanoparticles possess favourable physicochemical characteristics, excellent colloidal stability, potent antimicrobial efficacy, and significant anti-inflammatory activity. The synergistic interaction between silver nanoparticles and plant-derived phytochemicals appears to play a crucial role in enhancing these biological properties.

The plants *A. officinalis* and *P. santalinus* are botanical sources known for their therapeutic properties (Mohsenikia *et al.* 2020). Silver nanoparticles are well established for their applications in biomedicine (Bulle *et al.* 2016). This study aimed at formulating a wound healing gel using *A. officinalis* and *P. santalinus* with silver nanoparticles. This combination has resulted in a gel with proven anti-bacterial and anti-inflammatory properties (Masood *et al.* 2019). The green synthesis of silver nanoparticles (AgNPs) has emerged as an eco-friendly and sustainable approach, utilizing plant extracts with medicinal properties. Phytochemicals like flavonoids, polyphenols, and alkaloids found in *A. officinalis* and *P. santalinus* aid in the reduction of silver ions and the subsequent creation of stable silver nanoparticles. In addition to being safe for the environment, the green synthesis approach has the benefit of using natural molecules that have inherent therapeutic characteristics (Biswas *et al.* 2004).

The green synthesis of silver nanoparticles based on *P. santalinus* and *A. officinalis* formulation offers a viable path towards the development of effective antibacterial and anti-inflammatory medicines against wound infections (Younis *et al.* 2021) (Deepa *et al.* 2026). Plant extracts are used to support sustainable practices and to capitalize on the medical qualities that these botanical sources naturally possess. To confirm the effectiveness and safety of these silver nanoparticles, more investigation and clinical testing are necessary. This will open the door for the creation of innovative treatment approaches for wound healing and infection prevention (Medellín-Luna *et al.* 2019).

5. CONCLUSION

The present study investigates the green-synthesized silver nanoparticles by using plant extracts from *A. officinalis* and *P. santalinus* and is limited to in vitro antimicrobial and anti-inflammatory assays. In both

plants, the synthesis started at 10 min and ended by 3h. The formulation showed an antimicrobial activity against the oral wound pathogens *C. albicans*, *Lactobacillus*, *S. mutans*, and *S. aureus*. The disc impregnated with the formulation shows a larger zone of inhibition when compared to the antibiotic and silver nanoparticles. Hence, the results of the present study conclude that the silver nanoparticles synthesized by using *A. officinalis* and *P. santalinus* are an eco-friendly option. Further studies on toxicity, mechanism of action, wound-healing efficacy, and clinical applicability will be conducted.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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