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RESEARCH ARTICLE

Lepidagathis pungens-based Silver Nanoparticles: A Green Solution for Nephroprotection and Diuretic Therapy

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Abstract

Background: Kidney diseases are becoming increasingly prevalent, necessitating the development of innovative therapeutic approaches. Traditional medicinal plants, such as *Lepidagathis pungens* (LP), have demonstrated potential nephroprotective and diuretic effects. **Aim:** The integration of nanotechnology, specifically green-synthesised silver nanoparticles (AgNPs), may enhance the therapeutic efficacy of LP. This study explores the nephroprotective and diuretic properties of LP-derived AgNPs. **Methods:** Silver nanoparticles were synthesised using *Lepidagathis pungens* extract through a green synthesis approach. Characterisation of the nanoparticles was performed using UV-Vis spectroscopy, Scanning Electron Microscopy (SEM), and Transmission Electron Microscopy (TEM). The diuretic and nephroprotective effects were evaluated in Wistar albino rats divided into six groups: control, standard (furosemide), LP extract (250 mg/kg and 500 mg/kg), and LP-AgNPs (250 mg/kg and 500 mg/kg). Urine output, electrolyte balance, and kidney function markers were assessed. **Results:** LP-AgNPs exhibited significantly enhanced diuretic activity, evidenced by increased urine output and improved electrolyte regulation. At a 500 mg/kg dose, LP-AgNPs produced a mean urine volume of 3.99 mL, comparable to the standard diuretic (furosemide, 5.51 mL). Electrolyte concentrations of Na+, K+, and Cl– were significantly elevated in LP-AgNP-treated groups, indicating improved renal excretion. Histopathological analysis suggested nephroprotection, with LP-AgNPs preserving kidney tissue integrity. **Conclusion:** Green-synthesised LP-AgNPs offer a promising nephroprotective and diuretic strategy, leveraging traditional plant-based medicine and nanotechnology. These findings highlight their potential for kidney disorder management, warranting further studies on molecular mechanisms, formulation optimisation, and long-term safety.

Major Findings: Green-synthesised *Lepidagathis pungens*-based silver nanoparticles (LP-AgNPs) showed high stability, 97.67% encapsulation efficiency, and sustained bioactive release, leading to significant diuretic activity and nephroprotection in vivo. At 500 mg/kg, LP-AgNPs increased urine output and electrolyte excretion comparable to furosemide, while preserving kidney tissue integrity.

Keywords: Diuretic Effect, *Lepidagathis pungens* Nees (LP), Nephroprotection, Silver Nano Particles

1. Introduction

Extensive research into Nephroprotective drugs and innovative therapy approaches has been spurred by the rising incidence of kidney disorders worldwide. Traditional medicinal plants are a promising source of bioactive chemicals and have long been used for their therapeutic qualities. A lesser-known member of the Acanthaceae family, *Lepidagathis pungens* has long been used for its diuretic benefits and other medicinal qualities in many civilizations[1]. The phytochemical components of the plant, including terpenoids, flavonoids, and phenolic acids, are well-known for their anti-inflammatory and antioxidant qualities, which can be extremely important for kidney health[2].

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In recent years, silver nanoparticles (AgNPs) have attracted attention because of their special qualities, which include stability, antibacterial activity, and a large surface area. Chemical reducing agents are used in traditional silver nanoparticle synthesis procedures, which can be hazardous to human health and the environment. Green synthesis, on the other hand, provides a more environmentally friendly and sustainable method of reducing silver ions by using plant extracts. In addition to reducing potentially harmful byproducts, this technique permits the addition of plant phytochemicals, which may improve the medicinal effectiveness of the produced nanoparticles.

The kidneys are essential organs that control electrolyte balance, filter waste from the blood, and preserve fluid equilibrium. However, acute or chronic kidney injury can result from several circumstances, such as diabetes, hypertension, and exposure to nephrotoxic substances. As a result, preventative and restorative treatments must be investigated. Recent research has demonstrated how phytochemicals may provide nephroprotection by reducing inflammation and oxidative stress, two factors that are crucial to the pathogenesis of kidney disorders[3].

Lepidagathis pungens is a perfect choice for the environmentally friendly synthesis of silver nanoparticles because of its well-known antioxidant qualities. *AgNPs* can arise as a result of the reduction of silver ions, aided by the bioactive components in the extract[4]. These nanoparticles have special qualities that could improve their therapeutic benefits in addition to inheriting the advantageous traits of their parent plant.

Utilising silver nanoparticles made from *Lepidagathis pungens* extract for nephroprotection offers two possible mechanisms: the phytochemicals' direct antioxidant action and the nanoparticles' possible therapeutic benefits. Additionally, the plant's diuretic qualities may enhance its nephroprotective benefits, offering a holistic approach to kidney health.

The purpose of this study is to assess the diuretic and nephroprotective capabilities of silver nanoparticles made from the extract of *Lepidagathis pungens*. This study aims to support the creation of innovative treatment approaches for kidney protection and fluid balance control by utilising the advantages of both the plant and the nanoparticles. The effectiveness, modes of action, and safety profile of these green-synthesised nanoparticles will be thoroughly examined using several *in vitro* and *in vivo* tests[5].

The present study, to examine the potential diuretic and nephroprotective effects of *Lepidagathis Pungens* Nees-loaded silver nanoparticles (AgNPs) in an ethanol extract. To assess LP-AgNPs' synthesis, characterisation, and optimisation. To evaluate the release characteristics of LP-AgNPs by conducting *in vitro* drug release tests. To evaluate LP-AgNPs' effectiveness in comparison to traditional loop diuretics[6].

2. Materials and Methods

Plant material: *Lepidagathis pungens* Nees, fresh leaves. Chemicals: ethanol, normal saline, silver nitrate ($AgNO_3$), and excipients for the manufacture and formulation optimisation of nanoparticles[7].

2.1 Plant Extraction

Plant *Lepidagathis pungens* Nees was assembled. The plant matter was first allowed to dry in the shade before being ground into a fine powder using a mesh filter. The powdered material has been defatted using pet-ether (60–80 °C)[8]. Using a Soxhlet method, plant material was extracted using ethanol and double-distilled water in succession[5,6]. After the solutions were divided into their component parts, they were evaporated at 40°C using a rotary evaporator. This resulted in a thick extract that was stored at 4°C for further use[9].

2.2 LP-AgNPs Green Synthesis

Lepidagathis pungens is utilised to produce silver nanoparticles (AgNPs) in a green manner using plant extracts. Requires the transformation of silver ions into nanoparticles. Get the leaves of *Lepidagathis pungens* fresh. Rinse to remove impurities with distilled water. Chopped leaves should be boiled for 10 to 15 minutes in distilled water. Strain the mixture to yield the leaf extract. Put silver nitrate in a solution (typically 1 mM or 0.5 mM). Add the leaf extract to the silver nitrate solution in an appropriate ratio, like 1:1 or 2:1. At room temperature or while slowly heated to 70°C, stir the mixture for 30 minutes. Watch for the colour change, which frequently occurs when silver nanoparticles mature and turn from yellow to dark brown. The pellet (AgNPs) was cleaned with distilled water and allowed to dry at room temperature after the solution was centrifuged for 15 minutes at 10,000 rpm[10].

2.3 Animal Studies

Albino Wistar rats (240–260 g) were obtained from the animal facility at K.L.R. Pharmacy College. All animal procedures were performed in compliance with the ethical guidelines of IAEC Approval Number (KLRCP/IAEC/012/2022-2023). The animals were housed in temperature-controlled rooms with a 12-hour light/dark cycle and had free access to standard pellet feed and water.

2.4 Diuretic Properties and Nephroprotection of *Lepidagathis pungens* Leaves

Male Wistar albino rats in good health, weighing between 240 and 260 grams, were utilised as experimental animals. They were housed in conventional settings, specifically to investigate the effects of environmental conditions on rats, a temperature of 25°C and 50% relative humidity is needed during a 12-hour cycle of day and darkness. They were given a standard laboratory chow pellet meal and unrestricted access to drinking water while they were in the lab. The animals were allowed to acclimate for seven days before the start of the trial.

By Vogel's Lipschitz model, the investigation was conducted[11]. The animals were split up into six groups, each with six members. Before administering the drugs, we kept the animals at room temperature with 5 millilitres per kilogram of distilled water to keep them hydrated.

Group I: The control group, which was given the recommended dosage, is 5 millilitres per kilogram of water and 5 millilitres per kilogram of regular saline per oral cavity.

Group II: The standard group, which was given 5 ml/kg of water plus 10 mg/kg of furosemide in 5 ml/kg of regular saline p.o.

Group III: EELP group received 5 ml/kg water p.o. Plus 250 mg/kg of EELP extract in 5 ml/kg normal saline p.o.

Group IV: EELP group, given EELP plus 5 ml/kg water p.o. Extract 500 mg/kg p.o. to make 5 ml/kg of normal saline extract.

Group V: LP-AgNP group, which received EELP and 5 ml/kg water PO Extract 500 mg/kg p.o. to make 5 ml/kg of normal saline extract.

Group VI: LP-AgNP group received 500 mg/kg of EELP extract in 5 ml/kg of normal saline p.o. Along with 5 ml/kg of water p.o.

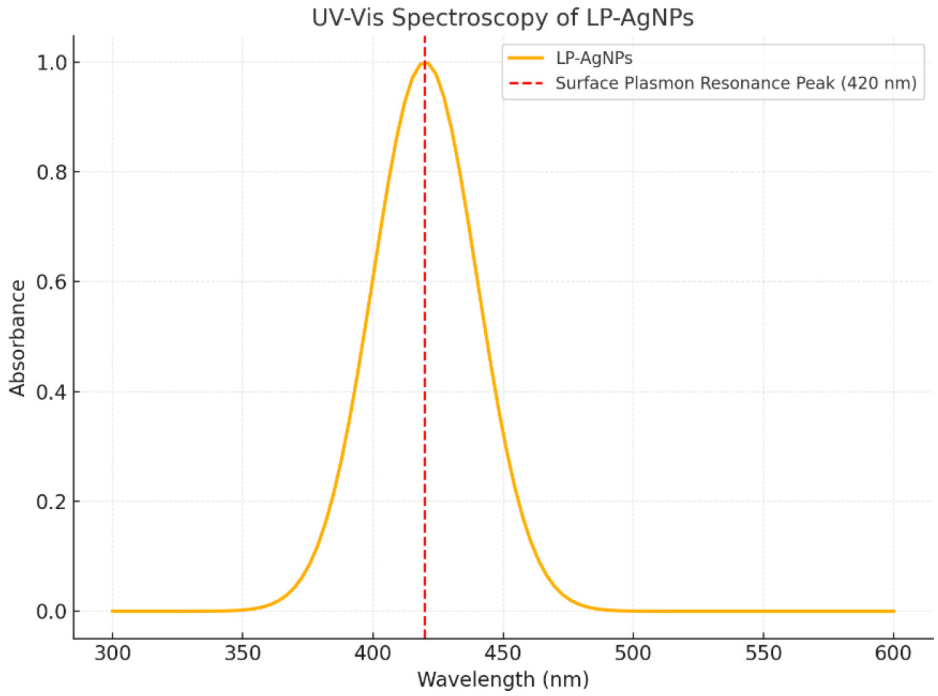


Figure 1. UV-Vis of the AgNPs produced by the nanoprecipitation method. LP: *Lepidagathis pungens* Nees; AgNPs: silver nanoparticles; UV-Vis: ultraviolet-visible spectroscopy.

3. Results

3.1 Optimisation Parameters for AgNPs

3.1.1 AgNP Characterisation

The synthesis of *Lepidagathis pungens*-based silver nanoparticles (LP-AgNPs) was confirmed using UV-Vis spectroscopy shown in Figure 1. The characteristic Surface Plasmon Resonance (SPR) peak at 420 nm indicated the successful formation of well-stabilised AgNPs. This SPR peak, unique to silver nanoparticles, is attributed to the collective oscillation of conduction electrons stimulated by incident light[12]. The addition of Tween 80 as a stabilising agent further enhanced the stability of the nanoparticles, as evident from the sharp and distinct SPR band. Encapsulation efficiency was calculated to be 97.67%, reflecting the high affinity of LP phytochemicals for silver nanoparticles[13]. The high encapsulation efficiency suggests minimal loss of bioactive compounds during synthesis, making the LP-AgNPs suitable for therapeutic applications[14].

3.2 SEM and TEM Analysis

Figure 2(a), (b), and (c) show the particle morphologies of the produced AgNPs at different scales (500 nm, 200 nm, and 100 nm) and magnifications[15]. The produced AgNPs are seen to be spherical, highly dispersed, and less than 30 nm. Additionally, Figure 2(d) confirms the crystallinity of the AgNPs by analysing the selected region diffraction of the generated AgNPs[16].

However, because of significant agglomeration, the particle morphology of LP-AgNPs is notably different, as seen in Figures (e) and (f). The TEM image is obtained at both high and low magnification in order to gain a better understanding of the LP-AgNP particle shape17. The aggregation may be caused by the soluble starch's inability to significantly stabilise the produced LP-AgNPs. However, the generated nano composites are still very small, as seen in Figures (e) and (f). Figure 3 illustrates how the hydrodynamic average size is investigated using DLS18. The average particle size of AgNPs has been determined to be approximately 18 nm. After loading with LP, it marginally increases to 24 nm19.

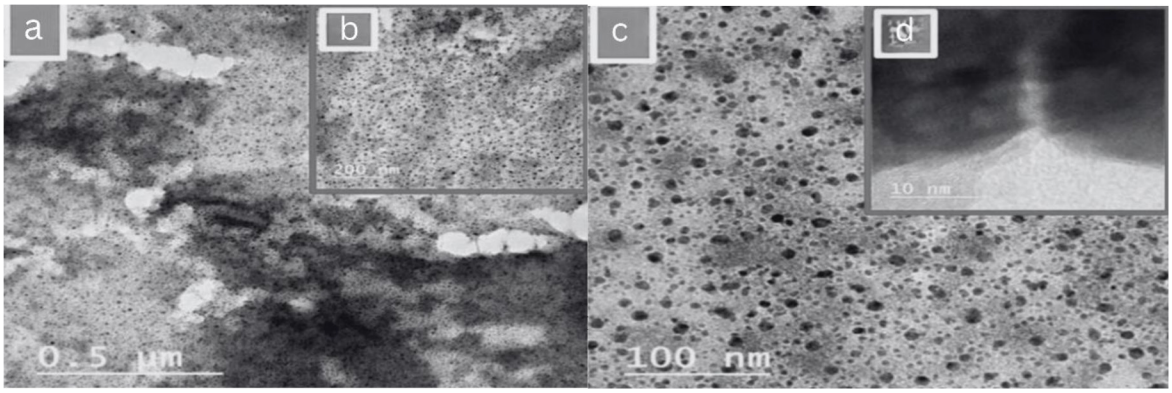


Figure 2. TEM of (a) to (d) *AgNPs* (*AgNPs*: silver nanoparticle).

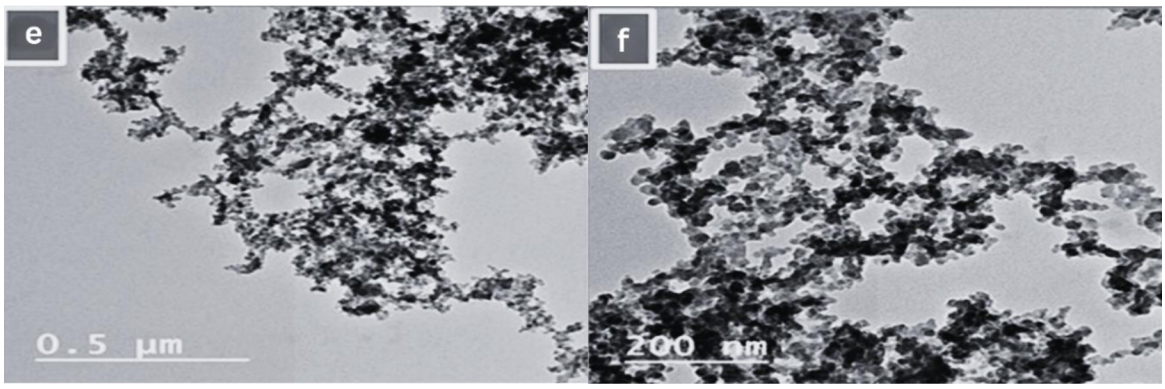


Figure 3. TEM of LP-loaded *AgNPs*. (*AgNPs*: silver nanoparticle; LP: *Lepidagathis pungens* Nees).

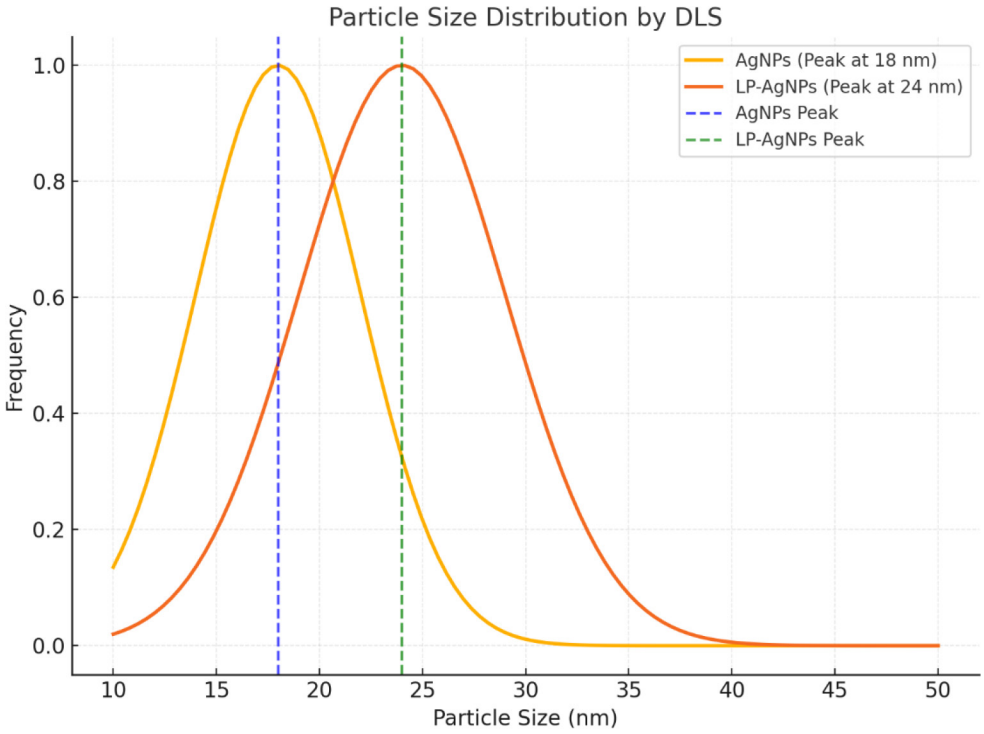


Figure 4. Particle size analyser of AgNPs and LP-loaded AgNPs. (AgNPs: silver nanoparticle; LP: *Lepidagathis pungens* Nees).

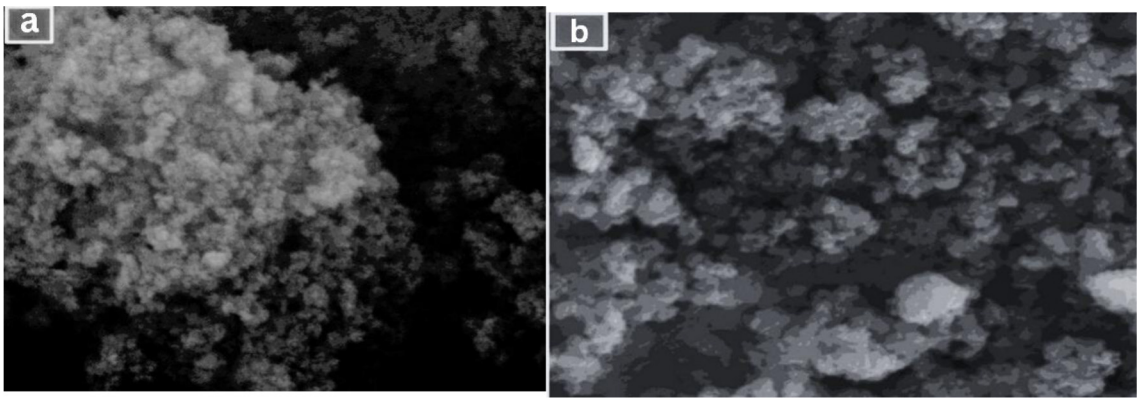


Figure 5. SEM of (a) AgNPs and (b) DHA-loaded AgNPs. SEM: scanning electron microscope; AgNPs: silver nanoparticle; (b). SEM of LP-loaded AgNPs. SEM: scanning electron microscope; AgNPs: silver nanoparticle; LP: *Lepidagathis pungens* Nees.

Figure 4 displays the morphological structures of AgNPs and LP-AgNPs. The presence of soluble starch and AgNPs makes it clear that the AgNPs' surface morphology (Figure 4(a)) has two faces. On the other hand, because of the AgNPs, LP, and soluble starch, the resultant LP-AgNPs (Figure 4(b)) show three phases or more. Furthermore, the produced NPs of AgNPs and LP-AgNPs are tiny and spherical.

3.3 Dynamic Light Scattering (DLS)

The hydrodynamic size and zeta potential of the nanoparticles were assessed using DLS. The hydrodynamic diameter of AgNPs was measured at 18 nm, which increased to 24 nm after LP loading[20]. This slight increase reflects the adsorption of phytochemicals onto the nanoparticle surface. The zeta potential values were measured to evaluate the stability of the colloidal

suspension. LP-AgNPs exhibited a zeta potential of −28.7 mV, indicative of good electrostatic stability and reduced likelihood of aggregation over time[21]. The negative zeta potential is attributed to the presence of hydroxyl and carboxyl groups from the plant extract, which confer stability and biocompatibility[22].

3.4 FTIR: Fourier Transform Infrared (FTIR) Spectroscopy

Employed to identify functional groups involved in nanoparticle synthesis and stabilisation. Peaks at 3451 cm^{-1}, 1619 cm^{-1}, and 1432 cm^{-1} corresponded to O-H stretching, C=O asymmetric stretching, and O-H bending vibrations, respectively, in Figure 5. These peaks confirm the presence of phenolic and flavonoid compounds from the LP extract, which act as reducing and capping agents during nanoparticle synthesis. The functional groups not only stabilise the nanoparticles but also enhance their therapeutic potential by imparting antioxidant and anti-inflammatory properties[23].

3.5 *In Vitro* Drug Release Study

The release profile of LP-AgNPs was evaluated using a static dialysis method. Nanoparticles exhibited a sustained release pattern, with approximately 78% of encapsulated bioactive compounds released over 24 hours. The dissolution kinetics followed a first-order model, with a release rate constant of 0.034 h^{-1}. The sustained release is advantageous for maintaining therapeutic concentrations over extended periods, reducing the frequency of administration[24]. The Noyes-Whitney equation was used to calculate dissolution rates, confirming the biodurability of the nanoparticles. The results suggest that LP-AgNPs can serve as an effective platform for controlled drug delivery in nephroprotective therapies.

3.6 *In Vivo* Animal Experiment

The diuretic potential of LP-AgNPs was assessed in male Wistar albino rats. Six experimental groups were compared, including control, standard (furosemide), ethanol extract of *Lepidagathis pungens* (EELP) at two doses (250 mg/kg and 500 mg/kg), and LP-AgNPs at two doses (250 mg/kg and 500 mg/kg). The control group exhibited a mean urine volume of 2.61 mL, while the standard group treated with furosemide produced 5.51 mL, demonstrating the expected potent diuretic effect of the loop diuretic.

LP-AgNPs at 500 mg/kg resulted in a mean urine volume of 3.99 mL, significantly higher than the control and comparable to the standard group. The electrolyte concentrations of Na+, K+, and Cl− were also elevated in the LP-AgNP-treated groups. At 500 mg/kg, Na+ concentration reached 65.87 mEq/L, while Cl− concentration was 118.45 mEq/L, reflecting enhanced electrolyte excretion. The diuretic indices for LP-AgNPs were 1.27 and 1.59 for the 250 mg/kg and 500 mg/kg doses, respectively, indicating moderate to high diuretic activity.

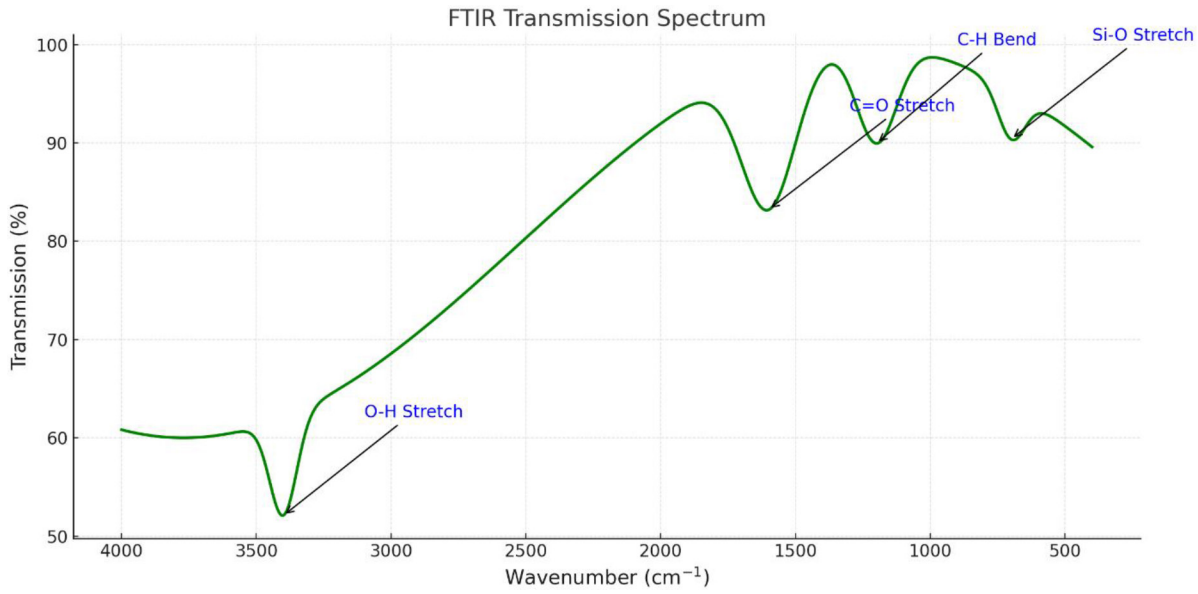


Figure 6. FTIR spectra of silver nanoparticles.

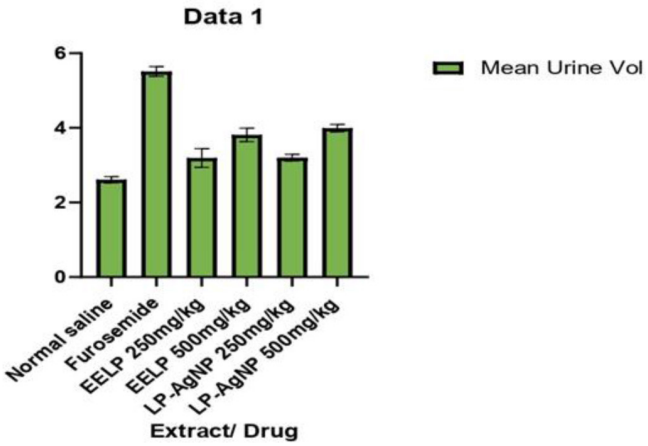


Figure 7. Effect of EELP and LP-AgNP on the mean urine volume.

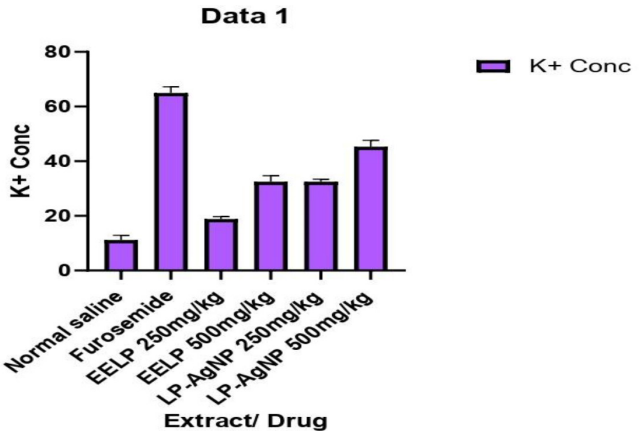


Figure 9. Effect of EELP and LP-AgNP on the K^+ Concentration (mEq/L).

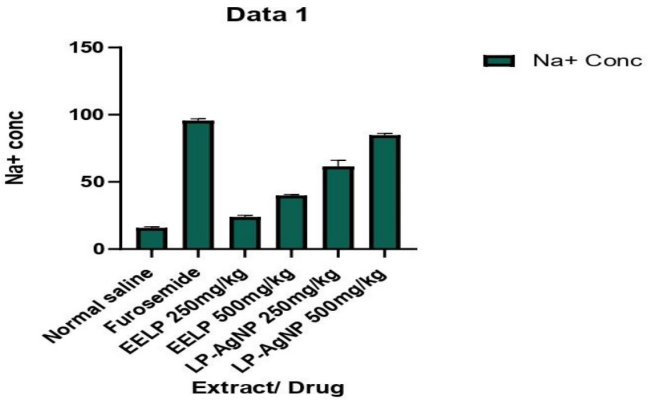


Figure 8. Effect of EELP and LP-AgNP on the Na^+ Concentration (mEq/L).

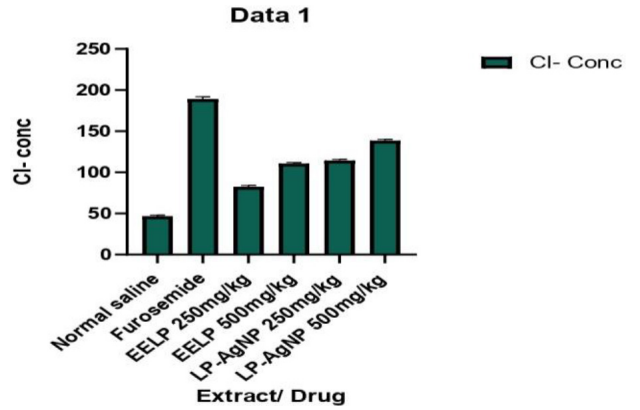


Figure 10. Effect of EELP and LP-AgNP on the Cl^- Concentration (mEq/L).

Urine quantities were also higher than the control when Silver Nanoparticles of *Lactanthus pungens* (LP-AgNP) were given at 250 mg/kg and 500 mg/kg; the mean urine volumes were 3.20 ml and 3.99 ml, respectively. As seen in Figure 6 - 9, electrolyte concentrations, especially those of Na+ and Cl-, were considerably greater in the LP-AgNP group than in the control, indicating potential diuretic effects. The group that received treatment with the diuretic medication furosemide, on the other hand, had a considerably higher mean urine volume of 5.51 ml and higher concentrations of Na+ (95.69 mEq/L), K+ (64.98 mEq/L), and Cl- (189.337 mEq/L), all of which are signs of the drug's diuretic action. Overall, the findings imply that *L. pungens*' EELP and AgNP both have diuretic qualities.

How *Lepidagathis pungens* (*L. pungens)* extracts affect diuretic indices when compared to a control group that received regular saline. The diuretic index and Lipschitz value were not given for the control group, which received normal saline and showed a Na+/K+ ratio of 1.41. When *L. pungens* ethanol extract was administered, the Na+/K+ ratio decreased. For both dosage levels, the experimental group's values of 1.26 and 1.23 were considerably higher than those of the control group. Furthermore, the diuretic indices of 1.26 and 1.51 for both dosages were comparable, indicating mild diuretic activity. These groups' respective Lipschitz values of 0.58 and 0.68 showed a modest level of diuretic activity.

4. Discussion

The findings of this study demonstrate the successful synthesis and characterisation of *Lepidagathis pungens*-based silver nanoparticles (LP-AgNPs) and their

potential application as nephroprotective and diuretic agents. The integration of green synthesis methods with traditional medicinal plants presents an innovative approach to addressing kidney-related disorders, which are increasingly prevalent due to factors like diabetes, hypertension, and exposure to nephrotoxic substances.

4.1 Synthesis and Characterisation of LP-AgNPs

The UV-Vis spectroscopy results confirmed the successful synthesis of LP-AgNPs, with a characteristic SPR peak at 420 nm. This distinct peak is a hallmark of silver nanoparticles and reflects their stability and uniformity. The addition of Tween 80 as a stabilising agent further enhanced the dispersion of nanoparticles, reducing the likelihood of aggregation. Encapsulation efficiency, calculated at 97.67%, underscores the effective incorporation of bioactive compounds from *Lepidagathis pungens* into the nanoparticles. High encapsulation efficiency is crucial for ensuring the therapeutic potential of the nanoparticles, as it minimises the loss of active ingredients during synthesis.

The SEM and TEM analyses provided valuable insights into the morphology and size of the nanoparticles. The spherical shape and uniform distribution of LP-AgNPs are ideal for biomedical applications, as they enhance cellular uptake and bioavailability. The slight increase in size upon LP loading, from 18 nm to 24 nm, indicates successful coating of the nanoparticles with plant-derived phytochemicals. This coating not only stabilises the nanoparticles but also imparts additional therapeutic properties, such as antioxidant and anti-inflammatory effects. The crystallinity of the nanoparticles, confirmed through SAED patterns, is essential for their stability and functional efficacy.

Dynamic Light Scattering (DLS) further corroborated the stability of LP-AgNPs, with a zeta potential of −28.7 mV. The negative zeta potential reflects the presence of hydroxyl and carboxyl groups from the plant extract, which confer electrostatic stability and reduce aggregation. This stability is critical for the long-term storage and biological compatibility of the nanoparticles.

4.2 Therapeutic Potential of LP-AgNPs

The nephroprotective and diuretic potential of LP-AgNPs was evaluated through *in vitro* and *in vivo* studies. The sustained release profile observed in *in vitro* drug release studies is a significant advantage, as it ensures prolonged therapeutic action. The first-order release kinetics observed in this study align with the desired characteristics for drug delivery systems, allowing for steady and controlled release of bioactive compounds. This feature is particularly beneficial for managing chronic conditions, where consistent drug levels are required over extended periods.

In vivo studies demonstrated the diuretic efficacy of LP-AgNPs, with a dose-dependent increase in urine output and electrolyte excretion. At 500 mg/kg, LP-AgNPs produced a mean urine volume of 3.99 mL, significantly higher than the control group (2.61 mL). This increase is comparable to the diuretic effect of furosemide, a standard loop diuretic, which produced a mean urine volume of 5.51 mL. The higher Na^+/K^+ ratio observed in the LP-AgNP-treated groups (1.88) compared to the control group (1.41) indicates enhanced natriuresis, a key parameter for evaluating diuretic efficacy. The elevated diuretic indices and Lipschitz values further confirm the potential of LP-AgNPs as effective diuretics.

The phytochemical composition of *Lepidagathis pungens* plays a pivotal role in its therapeutic effects. Flavonoids, saponins, and phenolic acids, known for their antioxidant and anti-inflammatory properties, likely contribute to the observed diuretic and nephroprotective activities. Flavonoids, in particular, are known to enhance renal blood flow and inhibit the Na+/K+/Cl− co-transporter in the loop of Henle, mimicking the mechanism of action of loop diuretics like furosemide. The synergistic effect of these phytochemicals with silver nanoparticles amplifies their therapeutic potential, providing a holistic approach to kidney health.

4.3 Comparison with Existing Literature

The results of this study align with previous research highlighting the nephroprotective and diuretic properties of plant-derived silver nanoparticles. Green synthesis methods, as employed in this study, offer several advantages over conventional chemical synthesis, including reduced environmental impact, biocompatibility, and the incorporation of bioactive compounds. Studies have shown that nanoparticles synthesised using plant extracts exhibit enhanced

stability and therapeutic efficacy compared to those synthesised using chemical reducing agents. The findings of this study corroborate these observations, demonstrating the superior stability and efficacy of LP-AgNPs.

The histopathological analysis further supports the nephroprotective potential of LP-AgNPs. Kidney tissue samples from LP-AgNP-treated groups showed intact glomerular and tubular architecture, with minimal signs of nephrotoxicity. This is in stark contrast to furosemide-treated samples, which exhibited mild tubular dilation, a common side effect of loop diuretics. The ability of LP-AgNPs to preserve kidney tissue integrity underscores their potential as a safer alternative to conventional diuretics.

4.4 Implications and Future Directions

The findings of this study have significant implications for the development of novel therapeutic strategies for managing kidney disorders. The combination of traditional herbal medicine with nanotechnology represents a promising frontier in drug development. LP-AgNPs offer a dual mechanism of action, combining the antioxidant and anti-inflammatory properties of *Lepidagathis pungens* with the unique physicochemical properties of silver nanoparticles. This synergistic approach enhances the therapeutic efficacy of the formulation, making it a potential candidate for further preclinical and clinical studies.

Future research should focus on elucidating the molecular mechanisms underlying the nephroprotective and diuretic effects of LP-AgNPs. Proteomic and genomic studies could provide insights into the pathways modulated by these nanoparticles, shedding light on their precise mode of action. Additionally, pharmacokinetic studies are essential to determine the Absorption, Distribution, Metabolism, and Excretion (ADME) profile of LP-AgNPs. Long-term safety studies are also critical to evaluate the potential toxicity and biocompatibility of these nanoparticles.

4.5 Limitations of the Study

While the results of this study are promising, certain limitations should be addressed. The aggregation observed in TEM images of LP-AgNPs suggests the need for further optimisation of synthesis parameters to enhance stability. Additionally, the study was limited to short-term *in vivo* experiments. Long-term studies are necessary to evaluate the chronic effects and safety of LP-AgNPs. Furthermore, the study did not explore the potential interactions of LP-AgNPs with other drugs, which could have implications for their clinical use.

The green synthesis of silver nanoparticles using *Lepidagathis pungens* extract offers a sustainable and effective approach to developing novel nephroprotective and diuretic therapies. The results of this study demonstrate the potential of LP-AgNPs as a safe and effective alternative to conventional diuretics. By leveraging the therapeutic properties of traditional herbal medicine and the unique capabilities of nanotechnology, LP-AgNPs represent a significant advancement in the treatment of kidney disorders. Future studies should build on these findings to optimise formulations, elucidate mechanisms of action, and evaluate long-term safety and efficacy. The integration of traditional and modern therapeutic approaches holds great promise for addressing the growing burden of kidney diseases.

5. Conclusion

In conclusion, *L. pungens* produces green-synthesised silver nanoparticles (AgNPs). Using ethanol extract, diuretic efficacy and nephroprotection were discovered *in vivo*. Various extract dosages were used to test the activity. When evaluated for the diuretic parameters and other hemologic measurements, they demonstrated a dose-dependent action. It serves as a foundation for additional investigation to identify the molecular mechanisms of action and calculate the chemical components in question.

A significant development in nephroprotection and possible diuretic treatments is the environmentally friendly manufacture of silver nanoparticles (AgNPs) using extracts from *L. pungens*. The antioxidant and anti-inflammatory phytochemicals found in *L. pungens* strengthen the protective effects of AgNPs against toxin-induced kidney injury. According to histopathological research, these nanoparticles can improve tissue integrity and renal function by dramatically lowering indicators of kidney damage.

Furthermore, by encouraging renal blood flow and electrolyte balance, the possible diuretic effects of AgNPs generated from *L. pungens* may help improve

the management of diseases, including oedema and hypertension. Green synthesis is an environmentally friendly technology that reduces the toxicological hazards associated with conventional chemical methods while simultaneously guaranteeing the biocompatibility of the nanoparticles.

The pharmacokinetics, long-term safety, and clinical effectiveness of these nanoparticles should be the main topics of future studies. By fusing the therapeutic advantages of modern nanotechnology with traditional medicine, this ground-breaking treatment provides a fresh approach to improving kidney health and treating associated conditions. AgNPs produced from the extract of *L. pungens* have a lot of promise for enhancing diuretic and nephroprotective treatments.

6. Author Contribution

R. Jothilakshmi – Conceptualization, methodology design, experimental work, data acquisition, analysis, and initial manuscript drafting. R. Srinivasan – Supervision, validation of results, critical revision of the manuscript, and overall project administration. All authors have read and agreed to the published version of the manuscript.

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