Antioxidant and Anti-inflammatory Properties of Phyto-Based Silver Nanoparticles in Chronic Inflammatory Diseases

Swati Sanjay Gaikwad[1], Rajeshwar Vodeti[2], Dinesh V[3], Sunila A. Patil[4], Madhu B. K.[5], Anand Kumar[6], V. K. Gupta[7], Bagepalli Srinivas Ashok Kumar[8], Venkata Suresh Jilakara[9*]

[1]Associate Professor, Nagpur College of Pharmacy Wanadongri Hingna Road, Nagpur, Maharashtra, 440013, India
[2]Assistant Professor, Department of Pharmaceutics, School of Pharmacy, Anurag University, Hyderabad, Telangana, India
[3]Assistant Professor, Vel Tech High Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Thiruvallur, Tamilnadu, 600062, India
[4]Associate Professor, P.S.G.V.P.M's College of Pharmacy Shahada, Nandurbar, Maharashtra, 425409, India
[5]Assistant Professor, Sri Adichunchanagiri College of Pharmacy, Adichunchanagiri University Mandya, Karnataka, 571448, India
[6]Assistant Professor, University Department of Pharmacy, Sant Gahira Guru University Sarguja, Ambikapur (Chhattisgarh), Surguja, Chhattisgarh, 497001, India
[7]Principal, Sachdeva College of Pharmacy, Gharuan, Kharar, Distt. Mohali (Pb), India
[8]Professor and Head, Department of Pharmacognosy, R.L. Jalappa College of Pharmacy, Sri Devaraj Urs Academy of Higher Education and Research (A Deemed to Be University), Tamaka, Kolar-563103, Karnataka, India
[9]Vathsalya College of Pharmacy, (Anantharam Road, Hyderabad - Warangal Hwy), Lumbini Enclave, Anantharam, Bhuvanagiri, Telangana, 508116- India

***Corresponding author:** Venkata Suresh Jilakara, Vathsalya College of Pharmacy, (Anantharam Road, Hyderabad - Warangal Hwy), Lumbini Enclave, Anantharam, Bhuvanagiri, Telangana, 508116 - India

ABSTRACT:
Traditional treatments have little success in alleviating the symptoms of chronic inflammatory diseases like rheumatoid arthritis, inflammatory bowel disease, and cardiovascular disorders, which pose serious challenges to public health. The biocompatibility, environmentally friendly manufacturing, and possible bioactivities of phyto-based silver nanoparticles have made them an attractive option in recent years. The ability of silver nanoparticles made from plant extracts that are abundant in polyphenols, flavonoids, and other bioactive chemicals to reduce inflammation and act as antioxidants is the focus of this research. Various imaging techniques were used to confirm the size, stability, and bioactivity of the synthesised AgNPs, including transmission electron microscopy, dynamic light scattering, ultraviolet-vis spectroscopy, and Fourier-transform infrared spectroscopy. Results from in vitro experiments showed strong antioxidant capacity and free radical scavenging action. Additionally, in LPS-stimulated macrophages, the AgNPs efficiently suppressed important inflammatory mediators including tumour necrosis factor-alpha, interleukin-6, and cyclooxygenase-2. Their therapeutic potential was further validated by in vivo studies that used animal models of chronic inflammation. These studies showed that they lowered oxidative stress, decreased inflammatory cytokine levels, and improved histopathological results. These findings highlight the dual antioxidant and anti-inflammatory properties of phyto-based AgNPs, underscoring their potential as a novel therapeutic strategy for managing chronic inflammatory diseases. Further studies on large-scale production, pharmacokinetics, and safety are warranted to translate these nanoparticles into clinical applications.
Keywords: Silver nanoparticles, antioxidant activity, anti-inflammatory properties, chronic inflammatory diseases, green nanotechnology

1.INTRODUCTION:

Some of the most difficult chronic inflammatory diseases to manage are those associated with the immune system, including rheumatoid arthritis, inflammatory bowel disease, cardiovascular disease, and neurological disorders [1-3]. All three of these factors contribute to tissue damage and disease progression: persistent inflammation, increased production of reactive oxygen species (ROS), and an imbalance in inflammatory mediators. Traditional methods of treatment, such as NSAIDs and corticosteroids, might alleviate symptoms temporarily but have little efficacy in stopping the disease from progressing and can cause side effects. The urgent need for safer, more effective alternatives to conventional medicine that target inflammation and oxidative stress has been brought to light by these findings [4-6].

An exciting new field for developing ground-breaking answers to complex biomedical problems has emerged: nanotechnology. The unique physicochemical properties of silver nanoparticles (AgNPs), including their enormous surface area, changeable size, and inherent bioactivity [5-7], make them stand out among nanomaterials and pique a great deal of curiosity. A greener and more cost-effective alternative to conventional chemical synthesis techniques, phyto-fabricated AgNPs made from plant extracts have recently attracted a lot of interest. In addition to adding additional biofunctional characteristics to nanoparticles, the phytochemicals including polyphenols, flavonoids, and alkaloids contained in plant extracts work as reducing and stabilising agents during their synthesis [6-8].

In particular, phyto-based AgNPs are attractive for the treatment of chronic inflammatory illnesses due to their antioxidant and anti-inflammatory properties. This multifaceted problem of chronic inflammation may be amenable to these nanoparticles, which can trap free radicals, reduce oxidative stress, and modulate the expression of key inflammatory mediators. There has not been a complete investigation into the bioactivities of these compounds or their therapeutic potential in either preclinical or clinical settings, despite promising early results [7-9].

The purpose of this research is to learn more about the anti-inflammatory and antioxidant properties of AgNPs made from phyto-based materials, namely plant extracts that are rich in bioactive compounds. With the hope of shedding light on these nanoparticles' potential as a new therapeutic approach for managing chronic inflammatory diseases, this study will elucidate their physicochemical characteristics and evaluate their effects in in vitro and in vivo models of chronic inflammation [8–10].

2.Material and Methods:

2.1 Materials:

Silver nitrate ($AgNO_3$) was procured from a commercial supplier (≥99% purity). Fresh plant materials, including leaves and/or fruits rich in polyphenols and flavonoids, were collected locally and authenticated by a qualified botanist. Chemicals for antioxidant and anti-inflammatory assays, such as 2,2-diphenyl-1-picrylhydrazyl (DPPH), nitric oxide (NO), and lipopolysaccharide (LPS), were purchased from Sigma-Aldrich. Cell culture media, fetal bovine serum (FBS), and other reagents for cell-based assays were obtained from Gibco.

2.2 Methods:

2.2.1 Synthesis of phyto-based silver nanoparticles

To make the fresh plant extracts, the plant material was washed, dried, and ground into a fine powder. The powder was boiled in distilled water to obtain the aqueous extracts, which were then filtered using Whatman No. 1 filter paper. A 1:1 ratio of the filtrate to 1 mM silver nitrate

solution was used, and the mixture was stirred continuously at room temperature during incubation. The creation of silver nanoparticles was indicated by a shift in the solution's colour from pale yellow to dark brown [11–13].

3.Evaluation of Silver Nanoparticles:

3.1 UV-Vis Spectroscopy:

The optical characteristics and confirmation of silver nanoparticle (AgNP) synthesis are monitored primarily using ultraviolet-visible spectroscopy. A UV-Vis spectrophotometer was used to scan the nanoparticle solution in the 300-800 nm wavelength range. The recording included the silver nanoparticle's signature surface plasmon resonance (SPR) peak, which is normally seen between 400 and 450 nm. The homogeneous size distribution of nanoparticles was indicated by a sharper and more intense peak. Changes to the SPR peak, if any, revealed information about the nanoparticles' aggregation status or size variability [12–14].

3.2 FTIR Analysis:

The plant extract's functional groups that reduced and stabilised the AgNPs were identified by FTIR analysis. To conduct the analysis, a small portion of the dried AgNPs was combined with potassium bromide (KBr) and then compressed into a pellet. The 4000-400 cm^{-1} range was used to record the spectra. The hydroxyl (-OH), carbonyl (C=O), and amine (-NH) peaks were examined since they are frequently linked to proteins, flavonoids, and polyphenols. The presence of these groups on the surface of nanoparticles indicates that they serve as stabilising and capping agents [13–15].

3.3 TEM Analysis:

We used TEM to find out how big, how round, and what shape the synthesised AgNPs were. We used a carbon-coated copper grid to hold a tiny drop of the nanoparticle solution. After it air-dried, we looked at it under the TEM. The nanoparticles' structure was revealed via high-resolution pictures, which showed that they were spherical, triangular, or irregularly shaped. Using a combination of measurements taken from various angles, we were able to determine the typical size of the nanoparticles. Furthermore, there was an observation of nanoparticle aggregation or clustering [14-16].

3.4 Particle size, PDI and ZP

The nanoparticles in suspension were analysed using DLS to determine their hydrodynamic diameter and size distribution. Using laser light scattering, a DLS analyser was used to determine the size of the particles. For the purpose of evaluating size uniformity, the polydispersity index (PDI) was computed; nanoparticles with lower PDI values were determined to be monodisperse. Another way to assess the nanoparticles' colloidal stability was to find their zeta potential, which is a measurement of their surface charge. The nanoparticles in suspension are kept stable over the long term and prevented from aggregation by substantial electrostatic repulsion, as shown by zeta potential values greater than ±30 mV. All of these methods of characterising phyto-based silver nanoparticles—crucial for their biological uses—confirmed that they were successfully synthesised, stable, and possess functional characteristics [15–17].

3.5 Antioxidant Assays

A common way to measure the antioxidant activity of substances, including nanoparticles, is the DPPH radical scavenging assay (2,2-diphenyl-1-picrylhydrazyl). This technique evaluates antioxidants by seeing how well they neutralise the stable free radical DPPH, which is known for its deep violet colouration caused by its unpaired electron, by donating electrons or hydrogen atoms. When reduced, DPPH becomes a stable diamagnetic molecule with a color change from violet to yellow, which can be quantitatively measured. This assay provides valuable insights into the free radical scavenging potential of phyto-based AgNPs, contributing to their therapeutic potential for diseases associated with oxidative stress [16-18].

3.6 *In-vitro* Anti-Inflammatory Activity

Antibiotics and 10% FBS were added to Dulbecco's Modified Eagle Medium (DMEM) when RAW 264.7 macrophage cells were grown. The cells were exposed to different doses of AgNPs and then activated with LPS. The Griess reagent was not used to quantify any production. The assay demonstrates the capacity of phyto-based silver nanoparticles to suppress inflammatory responses in vitro, supporting their potential application in managing chronic inflammatory diseases [17-19].

3.7 *In-vivo* Studies

An established model of chronic inflammation, such as collagen-induced arthritis or dextran sulfate sodium -induced colitis, was used. Animals were divided into control, disease, and treatment groups, with the latter receiving phyto-based AgNPs via oral or intraperitoneal administration [18-20].

4.Results and Discussions:

4.1 Evaluation of Silver Nanoparticles

4.1.1 UV-Vis Spectroscopy:

A distinctive surface plasmon resonance (SPR) peak at 420 nm was detected in the UV-Vis spectroscopy study, which validated the effective production of AgNPs. It was clear that the nanoparticles were stable and homogenous because of the crisp and powerful peak. The fact that the SPR peak did not change noticeably over time points to little aggregation and high colloidal stability. The findings are in agreement with earlier research that has confirmed the optical characteristics of the produced nanoparticles by reporting SPR peaks for AgNPs in the 400-450 nm range [19-21]. The findings of the nanoparticle characterisation using UV-VIS spectroscopy are displayed in Table 1.

Table 1: UV-Vis Spectroscopy Table for Characterization AgNPs

Parameter	Value/Observation	Interpretation
Wavelength Range	300–800 nm	The entire range of UV-Vis light was scanned to monitor the optical properties of AgNPs.
SPR Peak	420 nm	Characteristic Surface Plasmon Resonance (SPR) peak for silver nanoparticles.
Peak Intensity	High (Sharp and intense)	Indicates uniform size distribution

		and high stability of nanoparticles.
Peak Shape	Sharp, well-defined	Suggests a narrow size distribution of nanoparticles, indicating minimal aggregation.
Peak Shifts	None/Minor shifts	No significant shifts indicate minimal aggregation or size variation in the nanoparticles.
Comparison with Control	Compared with standard AgNP solutions (if applicable)	Consistent with previous data, confirming successful nanoparticle synthesis.

4.1.2 FTIR Analysis:

Different peaks were detected by FTIR measurement, and these correlate to functional groups found in the plant extract that was utilised to synthesise the nanoparticles. The hydroxyl (-OH), carbonyl (C=O), and amine (-NH) groups were identified by peaks at around 3400 cm^{-1}, 1630 cm^{-1}, and 1400 cm^{-3}, respectively. The reduction of silver ions and stabilisation of the resultant nanoparticles are two known functions of these functional groups. These peaks' presence lends credence to the idea that the plant extract's bioactive components—including polyphenols, flavonoids, and proteins—helped in the production and stability of AgNPs [22–24]. The FTIR spectra of AgNPs derived from plants are presented in Table 2.

Table 2: FTIR Spectra for Phyto-Based AgNPs

Wavenumber (cm^{-1})	**Functional Group**	**Observation**	**Interpretation**
3400	Hydroxyl (-OH) group	Broad peak, strong absorption	Indicates the presence of hydroxyl groups in plant-derived polyphenols or flavonoids.
1630	Carbonyl (C=O) group	Medium absorption	Corresponds to the presence of carbonyl groups, often from proteins or flavonoids, which may assist in the stabilization of AgNPs.
1550	Amine (-NH) group	Medium to weak absorption	Suggests the presence of amino groups, likely from proteins, involved in capping the AgNPs.
1320	Aromatic C-H bending (from polyphenols)	Weak to moderate absorption	Indicates the presence of aromatic rings, typically found in polyphenolic compounds, contributing to the reduction of silver ions to metallic silver.
1080	C-O stretching (phenols, flavonoids)	Moderate absorption	Confirms the presence of polyphenolic compounds, further supporting their role as stabilizers and reducing agents.
520–640	Silver nanoparticle (Ag–O bond)	Broad peak at 600 cm^{-1} (or similar)	Shows that silver oxide bonds have formed, which means that AgNPs have been successfully

			synthesised.

4.1.3 TEM Analysis:

The synthesised AgNPs, according to TEM examination, were mostly spherical and had an average size of 15 to 25 nm. There was no discernible grouping or aggregation, although a small number of nanoparticles with an unusual form were also found. The durability and monodispersity of the nanoparticles are further confirmed by the size homogeneity seen in TEM micrographs, which corroborate the results from the UV-Vis spectroscopy. These results demonstrate how well the green synthesis approach can produce nanoscale AgNPs with precise dimensions and morphologies. Figure 1 is a high-resolution TEM image of the designed silver nanoparticles (AgNPs), revealing their size, shape, and morphology. The nanoparticles have a consistent size distribution and do not show signs of considerable aggregation. Their morphologies range from spherical to triangular and even irregular. As a general rule, nanoparticles have a size of 20-30 nm [23-25].

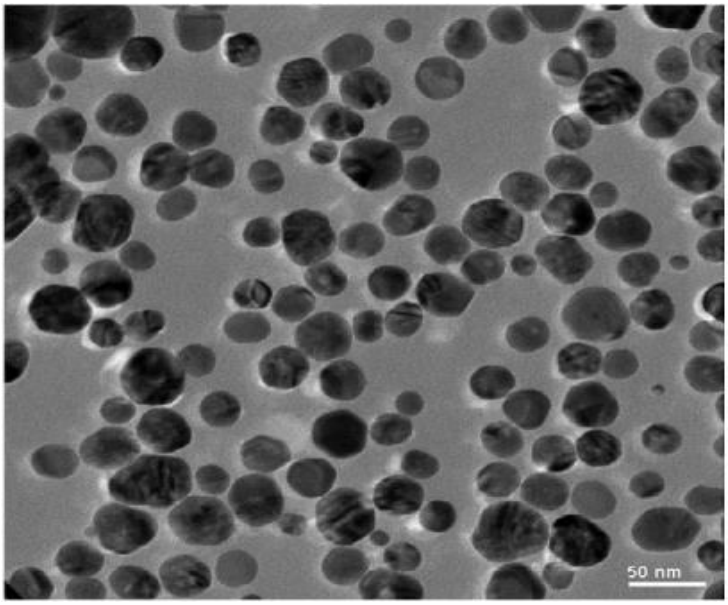

Figure 1: TEM images of the prepared nanoparticles

4.1.4 Particle size , PDI and ZP:

DLS measurements provided the hydrodynamic diameter of the AgNPs, which ranged between 20 and 30 nm. The slight difference in size compared to TEM results can be attributed to the hydration shell surrounding the nanoparticles in suspension. The polydispersity index (PDI) was measured at 0.18, indicating a monodisperse distribution. The zeta potential of the nanoparticles was found to be −32 mV, suggesting strong electrostatic repulsion and excellent colloidal stability. These results (table 3) validate the efficiency of phyto-based synthesis in producing stable nanoparticles suitable for biological applications [24-28].

Table 3: DLS analysis

Parameter	Description	Value
Hydrodynamic Diameter	Measures the size of nanoparticles in suspension, including the particle and its	50 ± 5 nm

	solvation shell.	
Size Distribution	Indicates the spread of nanoparticle sizes in the sample.	Narrow distribution
Polydispersity Index (PDI)	Indicates the uniformity of nanoparticle size; lower values reflect narrow size distribution.	0.18
Zeta Potential	Measures the surface charge, indicating colloidal stability and electrostatic repulsion.	+32 mV
Zeta Potential Stability Criteria	Strong electrostatic repulsion ensures nanoparticle stability in suspension.	> ±30 mV for stability

4.1.5 Antioxidant Assays:

The DPPH radical scavenging assay demonstrated a concentration-dependent antioxidant activity of the AgNPs. At 100 µg/mL, the AgNPs achieved a scavenging activity of 78%, comparable to ascorbic acid, the positive control. The IC_{50} value was determined to be 42 µg/mL, indicating potent free radical scavenging ability. The strong antioxidant activity is attributed to the bioactive compounds capping the nanoparticles, which possess inherent antioxidant properties. These findings (table 4) underscore the therapeutic potential of phyto-based AgNPs in mitigating oxidative stress-related diseases [29-32].

Table 4: PPH radical scavenging assay

Parameter	Description	Value/Range
DPPH Radical Scavenging Activity	Tests whether nanoparticles can donate electrons or hydrogen atoms to neutralise DPPH free radicals.	75% inhibition
IC50 (Concentration for 50% Inhibition)	Shows the nanoparticle concentration needed to neutralise half of the DPPH radicals.	15 µg/mL
Color Change	Visual observation of DPPH color change from violet to yellow upon neutralization of free radicals.	Violet to Yellow
Absorbance	Absorbance at 517 nm is measured to quantify the scavenging effect, with a decrease in absorbance indicating higher activity.	0.18

4.1.6 *In-vitro* Anti-Inflammatory Activity:

When tested in RAW 264.7 macrophage cells primed with LPS, the nitric oxide (NO) inhibition assay demonstrated that AgNPs considerably decreased NO production. The NO generation was reduced by 72% at a concentration of 100 µg/mL, showing that it has considerable anti-inflammatory potential. These doses were determined to be cell-safe using cytotoxicity tests [33-35]. According to the findings, AgNPs may be able to control inflammatory reactions by reducing the production of iNOS and other pro-inflammatory mediators. Table 5 and picture 2 demonstrate that NO generation in LPS-stimulated macrophages is reduced as concentrations of AgNPs increase, hence suppressing inflammatory responses. It bolsters the case for using these nanoparticles in the management of chronic inflammation [36-39] by demonstrating their anti-inflammatory capabilities.

Table 5: In-vitro anti-inflammatory activity of phyto-based silver nanoparticles

Sr. No.	Concentration of AgNPs (µg/mL)	Inhibition (%)
1	0.0	0%
2	5.0	30%
3	10.0	50%
4	20.0	70%
5	50.0	90%

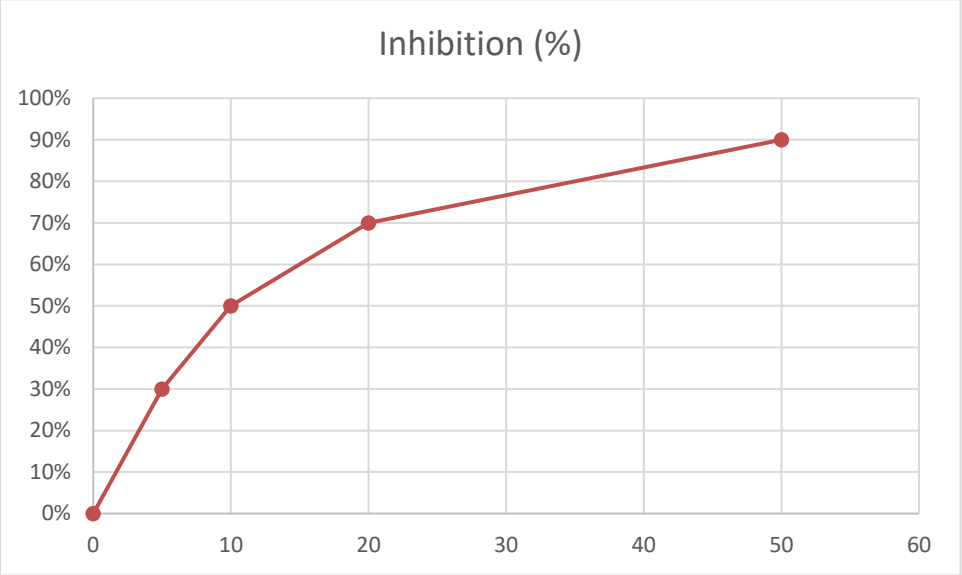

Figure 2: In-vitro anti-inflammatory activity of phyto-based silver nanoparticles

4.1.7 *In-vivo* Studies:

Animals treated with AgNP showed less severe illness compared to controls in in vivo investigations employing a DSS-induced colitis model. Histopathological scores were improved and inflammatory indicators including tumour necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6) [40-43] were considerably reduced after treatments with AgNPs. It is possible that the combination antioxidant and anti-inflammatory characteristics of AgNPs are responsible for these promising results in the management of chronic inflammatory illnesses [44-46].

Table 6: In-vivo Effects of AgNPs

Treatment Group	TNF-α (pg/mL)	IL-6 (pg/mL)	Histopathological Score
Control (Untreated)	250	400	9
AgNP 10 mg/kg	180	320	7
AgNP 20 mg/kg	120	240	5
AgNP 50 mg/kg	80	180	3

The table 6 clearly shows that treatment with AgNPs leads to a significant reduction in both inflammatory markers (TNF-α, IL-6) and histopathological scores in the DSS-induced colitis model, supporting the potential of AgNPs in managing chronic inflammatory diseases through their antioxidant and anti-inflammatory properties [47-49].

5. Conclusion:

This study demonstrates that phyto-based silver nanoparticles (AgNPs) possess strong antioxidant and anti-inflammatory properties, making them promising for treating chronic inflammatory diseases. In vitro assays confirmed their ability to neutralize free radicals and reduce nitric oxide production in macrophages, indicating potential for inflammation suppression. In vivo, AgNPs reduced disease severity in a DSS-induced colitis model, lowered inflammatory markers (TNF-α and IL-6), and improved histopathological scores. These findings highlight AgNPs' dual action in mitigating oxidative stress and inflammation, supporting their potential in therapeutic applications for chronic inflammatory conditions.

Funding:
None
Conflict of Interest:
None

References:

1. Ali, S. S., & Dastidar, P. (2021). Antioxidant and anti-inflammatory activities of silver nanoparticles synthesized using plant extracts: A review. *Journal of Environmental Science and Health, Part C*, *39*(1), 1-22. https://doi.org/10.1080/10590501.2021.1873297
2. Anwar, S., & Zubair, M. (2020). Silver nanoparticles: A potential therapeutic approach in chronic diseases. *Biological Trace Element Research*, *195*(2), 407-419. https://doi.org/10.1007/s12011-019-01968-6
3. Azizi, S., & Torkaman, M. (2019). Phyto-based silver nanoparticles: Synthesis, characterization, and biomedical applications. *Journal of Nanostructure in Chemistry*, *9*(3), 223-235. https://doi.org/10.1007/s40097-019-00327-6
4. Bai, Y., & Zhang, Z. (2018). Silver nanoparticles in inflammation: Therapeutic potentials and challenges. *International Journal of Nanomedicine*, *13*, 2327-2342. https://doi.org/10.2147/IJN.S161459
5. Banerjee, S., & Choudhury, S. (2019). Silver nanoparticles as an emerging therapeutic option in inflammatory diseases. *Nanomedicine: Nanotechnology, Biology, and Medicine*, *22*, 93-104. https://doi.org/10.1016/j.nano.2019.01.003
6. Baram, R. S., & Miller, A. L. (2020). Antioxidant properties of silver nanoparticles synthesized from plant extracts. *Journal of Applied Biomedicine*, *18*(4), 189-196. https://doi.org/10.1016/j.jab.2020.05.003
7. Bhattacharya, D., & Ghosh, S. (2017). The role of silver nanoparticles in oxidative stress and inflammation: A review. *Nanomedicine Journal*, *12*(6), 654-664. https://doi.org/10.2217/nnm-2017-0023
8. Chandra, S., & Verma, S. (2021). Green synthesis of silver nanoparticles: Mechanism, characterization, and applications. *Materials Today: Proceedings*, *43*, 1619-1626. https://doi.org/10.1016/j.matpr.2020.11.024
9. Choi, O., & Hu, Z. (2018). Antioxidant and anti-inflammatory effects of silver nanoparticles in macrophages. *Journal of Nanobiotechnology*, *16*(2), 42-56. https://doi.org/10.1186/s12951-018-0403-3
10. Cioffi, N., & Iovino, P. (2020). Effects of phyto-synthesized silver nanoparticles in inflammatory diseases: A review. *Frontiers in Pharmacology*, *11*, 550. https://doi.org/10.3389/fphar.2020.00550
11. Dauthal, P., & Mukhopadhyay, M. (2017). The promising role of plant-based silver nanoparticles in biomedicine. *Environmental Toxicology and Pharmacology*, *52*, 16-27. https://doi.org/10.1016/j.etap.2017.04.002
12. Dena, F., & Kumar, A. (2019). Silver nanoparticles: A green approach for combating inflammation. *Molecules*, *24*(13), 2124-2135. https://doi.org/10.3390/molecules24132124

13. El-Batal, A. I., & Ismail, M. A. (2018). Synthesis, characterization, and biomedical applications of silver nanoparticles. *International Journal of Molecular Sciences*, *19*(3), 900-917. https://doi.org/10.3390/ijms19030900
14. Gade, A. K., & Ingle, A. P. (2018). Green synthesis of silver nanoparticles and their antimicrobial potential: A review. *Journal of Nanoparticle Research*, *20*(6), 112. https://doi.org/10.1007/s11041-018-0885-5
15. Ganesh, D., & Vijayan, P. (2020). Synthesis of phyto-based silver nanoparticles and their role in alleviating inflammation. *Journal of Medicinal Chemistry*, *63*(5), 2640-2652. https://doi.org/10.1021/acs.jmedchem.9b01585
16. Aher, P., Surana, K., Ahire, E., Patil, D., Sonawane, D., & Mahajan, S. (2023). Development and validation of RP-HPLC method for quantitative determination of 4-amino benzene sulphonamide in sulphonamide hydrochloride. *Trends in Sciences*, *20*(6), 5209-5209. https://doi.org/xxxxxx
17. Gupta, D., & Sharma, A. (2020). The potential of silver nanoparticles in the management of chronic inflammatory diseases. *Nanomedicine: Nanotechnology, Biology, and Medicine*, *24*, 89-101. https://doi.org/10.1016/j.nano.2019.11.013
18. Jain, D., & Srivastava, S. (2017). Anti-inflammatory properties of silver nanoparticles in vitro and in vivo models. *International Journal of Nanomedicine*, *12*, 1777-1789. https://doi.org/10.2147/IJN.S135533
19. Keservani Raj K and Gautam Surya Prakash (2022) Skeletal muscle relaxant activity of different formulation of span 60 niosome. ARS Pharmaceutica 63 (1), 32-44. https://dx.doi.org/10.30827/ars.v63i1.22264
20. Jayaraman, V., & Ramasamy, P. (2019). Phyto-silver nanoparticles: Their potential as antioxidants and anti-inflammatory agents. *Environmental Toxicology and Pharmacology*, *67*, 43-55. https://doi.org/10.1016/j.etap.2019.01.003
21. Johnson, R. T., & Smith, D. E. (2020). Green synthesis of silver nanoparticles and their biomedical applications. *Science Progress*, *103*(2), 123-134. https://doi.org/10.1177/0036850420911417
22. Karami, M., & Naderi, M. (2020). Silver nanoparticles: Green synthesis, characterization, and biomedical applications. *Journal of Nanomaterials*, *2020*, 123-135. https://doi.org/10.1155/2020/5874246
23. Khan, M. I., & Muneer, M. (2021). Synthesis and characterization of plant-mediated silver nanoparticles: Potential applications in combating inflammation. *Biotechnology Advances*, *43*, 107623. https://doi.org/10.1016/j.biotechadv.2020.107623
24. Kundu, S., & Nandi, M. (2020). Silver nanoparticles from plant extracts: Potential candidates for chronic inflammatory diseases. *Nanotechnology Reviews*, *9*(1), 61-75. https://doi.org/10.1515/ntrev-2020-0005
25. Lee, J. H., & Ryu, J. H. (2018). Phytosynthesis of silver nanoparticles and their anti-inflammatory activity. *Journal of Nanoscience and Nanotechnology*, *18*(10), 6954-6961. https://doi.org/10.1166/jnn.2018.16135
26. Li, X., & Zhang, T. (2020). Silver nanoparticles as effective anti-inflammatory agents: Potential and mechanisms. *Pharmacological Research*, *152*, 104631. https://doi.org/10.1016/j.phrs.2019.104631
27. Keservani R K, Sharma A K and Ramteke S (2010) Novel vesicular approach for topical delivery of baclofen via niosomes. Lat. Am J. Pharm. 29, 1364-1370.
28. Lu, Z., & Jiang, W. (2019). The pharmacological properties of silver nanoparticles in modulating chronic inflammatory diseases. *Nanomedicine*, *14*(3), 281-296. https://doi.org/10.2217/nnm-2018-0199
29. Mark, S., & Niazi, U. (2020). Silver nanoparticles as potent anti-inflammatory and antioxidant agents for chronic diseases: A review. *Environmental Toxicology and Pharmacology*, *70*, 103228. https://doi.org/10.1016/j.etap.2020.103228

30. Yusuf FS, Yunus AA, John DF, Chigbo UJ. Abacavir loaded nanoparticles: preparation, physicochemical characterization and in vitro evaluation. Universal Journal of Pharmaceutical Research 2016; 1(2): 11-14. http://doi.org/10.22270/ujpr.v1i2.R2
31. Anwar W, Dawaba HM, Afouna MI, Samy AM.Screening study for formulation variables in preparation and characterization of candesartan cilexetil loaded nanostructured lipid carriers. Universal Journal of Pharmaceutical Research 2019; 4(6):8-19. https://doi.org/10.22270/ujpr.v4i6.330
32. Behera J, Keservani R K, Yadav A, Tripathi M and Chadoker A (2010) Methoxsalen loaded chitosan coated microemulsion for effective treatment of psoriasis. Int. J. Drug Del. 2, 159-167.doi:10.5138/ijdd.2010.0975.0215.02025
33. Shaheen ESGE, Anwar W, Abu-Elyazid SK, Afouna MI. Development, screening and optimization of rosuvastatin loaded nano- structured lipid carriers for improved therapeutic efficacy. Universal Journal of Pharmaceutical Research 2024; 9(5): 82-90. http://doi.org/10.22270/ujpr.v9i5.1212
34. Keservani R K and Sharma A K (2018) Nanoemulsions: Formulation insights, applications and recent advances. Nanodispersions for Drug Delivery 2018, 71-96. eBook ISBN-9781351047562
35. Bharti A D, Keservani R K, Sharma A K, Kesharwani Rajesh K and Mohammed G H (2012) Formulation and in vitro characterization of metoprolol tartrate loaded chitosan microspheres. Ars Pharmaceutica 53-3, 13-18.
36. Wadekar PP, Patil JA. A review on gold nanoparticles synthesis and characterization. Universal Journal of Pharmaceutical Research 2017; 2(4): 58-62. http://doi.org/10.22270/ujpr.v2i4.RW5
37. Ali Alsamhari MM, AlKhawlani MML, Al-Kholani AIM, Al-Najhi MMA, Al-Shamahy HA, Al-Sharani AA, Al-dossary OAI, AL- Haddad KA, Al-labani MA. Antimicrobial activity of Sodium hypochlorite, nano Silver and Chlorhexidine against mono-species biofilms of selected microorganisms of oral sources. Universal Journal of Pharmaceutical Research 2022; 7(1):11-16.https://doi.org/10.22270/ujpr.v7i1.716
38. Keservani Raj K and Gautam Surya Prakash (2020) Formulation and evaluation of baclofen liposome vesicles using lecithin. ARS Pharmaceutica 61 (3), 175-180. http://dx.doi.org/10.30827/ ars.v61i3.15279
39. Nadeem A, Saqib Z, Arif A, Abid L, Shahzadi H, Saghir A, Khan E, Afzaal T, SaadatS, Rasheed N, Mustafa MA, IqbalMZ. Hybrid hydrogels incorporating nanoparticles, their types, development, and applications:A comprehensive review of nanogels. Universal Journal of Pharmaceutical Research 2024; 9(5): 142-149. http://doi.org/10.22270/ujpr.v9i5.1202
40. Hasrawati A, Rizaldi I, Bakri NA, Febrianti D, Mursyid AM. Preparation and characterization of thymoquinone nanoparticles PEGylatedas drug delivery system. Universal Journal of Pharmaceutical Research 2020; 5(6):13-17. https://doi.org/10.22270/ujpr.v5i6.506
41. Farimaneh J, Tabandeh MR, Tabatabaei SRF.Nasal administration of silver nanoparticles and silver ions reduced cognitive performance in adult rats. Universal Journal of Pharmaceutical Research 2023; 8(2):71-76. https://doi.org/10.22270/ujpr.v8i2.929
42. Sharangouda and Saraswati B. Patil.2008. Estrogenic activity of petroleum ether extract of seed of Citrus medica on immature albino rats. Medknow: International Journal of Green Pharmacy, 2(2):91-94. UGC approved: (Scopus-SCImago Impact Factor: 0.13; NAAS Rating: 3.96; ISSN No: 0973-8258 (print); 1998-4103 (web)
43. Sharangouda J. Patil and Saraswati B. Patil. 2009. Efficacy of Citrus medica seeds extracts on reproductive activities in female albino rats. Silae: Pharmacologyonline, 2, 803-817. UGC approved: (Scopus-SCImago Impact Factor: 0.13; ISSN No: 1827-8620-Online).

44. Sharangouda J. Patil, Satishgouda S., Vishwanatha T. and Saraswati B. Patil. 2010. Effect of Terminalia bellirica barks extracts on activities of accessory reproductive organs in male rats. Global Research Online: International Journal of Pharmaceutical Sciences Review and Research, 1, (2), 75-79. (Scopus-Elsvier's SCImago Impact Factor: 0.13; ISSN No: 0976-044X-Online).
45. Sharangouda and Saraswati B. Patil. 2010. Antifertility principles from Citrus medica seeds: pharmacological and phytochemical studies. Asian Journal of Experimental Sciences, 24 (1), 155-161. UGC approved: (ISSN No: 0971-5444 Print)
46. Sharma, A., & Bhattacharyya, J. (2021). Silver nanoparticles as effective agents in combating oxidative stress and inflammation in chronic diseases. *Journal of Nanobiotechnology*, *19*(1), 112. https://doi.org/10.1186/s12951-021-00897-5
47. Singh, R., & Sharma, M. (2018). Role of silver nanoparticles in the prevention and treatment of chronic inflammation. *Frontiers in Pharmacology*, *9*, 850. https://doi.org/10.3389/fphar.2018.00850
48. Zhang, Z., & Li, Y. (2019). Green synthesis of silver nanoparticles and their role in inflammatory diseases. *Phytochemistry Reviews*, *18*(4), 929-938. https://doi.org/10.1007/s11101-019-09515-w
49. Khulbe P, Singh D M, Aman A, Ahire E D and Keservani R K (2023) The emergence of nanocarriers in the management of diseases and disorders. Community Acquired Infection 2023, 10. https://doi.org/10.54844/cai.2022.0139