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Review article

Flower Extract for the Synthesis of Silver Nanoparticles: A Review

Mukhtar Lawal Abubakar[1, 2] Aakriti Vyas[1], Krishan Kumar[1], and Gaurav Sharma[1*]

[1]School of Applied Sciences, Suresh Gyan Vihar University, Jaipur, Rajasthan, India

[2]Science Laboratory Technology Department, Federal Polytechnic, Kaura Namoda, Zamfara State, Nigeria

*Corresponding author's e-mail addresses: gaurav.sharma@mygyanvihar.com

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Abstract

Silver nanoparticles (AgNPs) have garnered considerable attention in nanotechnology due to their distinctive physicochemical properties and notable antimicrobial potential. However, conventional synthesis techniques often rely on toxic reagents and energy-intensive processes, posing risks to both human health and the environment. In contrast, green synthesis particularly utilizing flower extracts has emerged as a sustainable and eco-friendly alternative. This review focuses on the biosynthesis of AgNPs using floral sources, emphasizing the critical role of phytochemicals like flavonoids, terpenoids, and phenolic compounds in nanoparticle formation and stabilization. Numerous flowers, such as *Dillenia indica*, *Curcuma longa*, and *Malva sylvestris*, have demonstrated efficacy in generating AgNPs with promising antibacterial, antioxidant, and catalytic activities. Additionally, the review outlines various synthesis approaches, including green, ultrasound-assisted, and microwave-assisted methods along with standard characterization techniques like UV-Vis spectroscopy, FTIR, SEM, and TEM. Applications of flower-derived AgNPs span across biomedicine (e.g., antimicrobial and anticancer therapies) and environmental technologies (e.g., wastewater treatment and dye degradation). While the green synthesis approach offers numerous advantages, challenges such as process scalability, consistency in synthesis, and the lack of comprehensive in vivo studies

remain. Overcoming these barriers through focused research and cross-disciplinary efforts could significantly advance the practical deployment of flower-mediated AgNPs in sustainable healthcare and environmental solutions.

Introduction

Nanotechnology has become a groundbreaking area of research and innovation, with silver nanoparticles (AgNPs) standing out due to their exceptional chemical and physical characteristics, particularly their potent antimicrobial properties. Conventional methods for producing AgNPs typically rely on physical or chemical techniques that demand high energy input and involve the use of harmful chemicals. These practices raise serious environmental and health-related concerns. To address these issues, scientists have increasingly turned to green synthesis techniques, which employ biological systems—most notably, plant-derived materials—as sustainable and economical alternatives (Ahmed et al., 2016; Huq et al., 2022).

Among the various plant-derived sources explored for nanoparticle synthesis, flower extracts have shown remarkable potential. This is largely due to their diverse array of bioactive compounds, such as flavonoids, phenolics, terpenoids, and tannins, which serve as both reducing and stabilizing agents during nanoparticle formation (Kanniah et al., 2020; Akhter et al., 2024). For example, *Dillenia indica* flowers have been successfully used to synthesize spherical AgNPs with notable antibacterial and antioxidant properties (Islam et al., 2024). Similarly, flower extracts from *Curcuma longa* have produced AgNPs around 5 nm in size, demonstrating effective antibacterial action against *Staphylococcus aureus* and *Escherichia coli* (Rajak et al., 2023). Other successful examples include AgNP synthesis from *Fritillaria* flowers (Hemmati et al., 2019) and *Wedelia urticifolia*, both of which exhibited promising antimicrobial properties (Behravan et al., 2019).

More recent investigations have broadened the range of flower species utilized for green nanoparticle synthesis. For instance, extracts from *Malva sylvestris* flowers yielded AgNPs that were not only effective against *E. coli* and *S. aureus* but also excelled in catalytic degradation of dyes (Ebrahimzadeh et al., 2021; Darroudi et al., 2021). AgNPs synthesized from *Salvia sclarea* (clary sage) flowers demonstrated strong antibacterial potential and environmentally friendly characteristics, indicating suitability for biomedical use (Bibi et al., 2024). Likewise, flower extracts from *Mangifera indica* (mango) and *Hemigraphis colorata* were shown to produce AgNPs with significant antimicrobial activity (Raza et al., 2020; Bora & Debnath, 2021).

Collectively, these studies underscore the adaptability and effectiveness of floral extracts in

facilitating AgNP synthesis. Plant-based nanoparticle production offers clear advantages, including the avoidance of hazardous chemicals, cost-effectiveness, and the feasibility of scaling up the process. Furthermore, the characteristics of the resulting nanoparticles—such as size, shape, and bioactivity—can be fine-tuned by adjusting parameters like pH, temperature, and extract concentration, making this method highly versatile for applications in healthcare, food safety, and environmental cleanup (Abada et al., 2023; Huq et al., 2022).

The aim of this review is to present a comprehensive overview of AgNP synthesis using flower extracts. It aims to detail the underlying mechanisms, highlight the morphological and functional features of the nanoparticles, and examine their practical uses. By synthesizing current findings, the review emphasizes the largely untapped potential of floral resources in nanotechnology and encourages future interdisciplinary research in this promising domain.

The major objectives of this study are summarized as follows.

- **To systematically review and compare recent advancements in the green synthesis of silver nanoparticles (AgNPs) using flower extracts,** emphasizing the synthesis methods, technologies, and plant species used across various studies**.**
- **To develop a comprehensive taxonomy** that categorizes the key components, processes, and outcomes of flower-mediated AgNP synthesis, providing a structured understanding of current research directions and practices.
- **To identify major challenges and propose practical solutions** related to the scalability, characterization, and biomedical applications of flower-extract-mediated AgNPs, supporting future research and commercial translation.

The remainder of this paper is organized as follows. Section II presents the summary of the-state-of-the-art methods used in the synthesis of silver Nanoparticles from flower extracts. Section III presents the inferences drawn from the summary of the state of the art methods. Section IV presents the proposed taxonomy of the flower extract-based synthesis of silver Nanoparticles. Section V presents the various challenges and solutions in the synthesis of silver Nanoparticles from flower extracts. Lastly, Section VI conclude the study.

State-of-the-art Methods

Green synthesis of silver nanoparticles (AgNPs) using flower extracts has emerged as a promising area in nanobiotechnology due to its eco-friendliness, low cost, and biocompatibility. Numerous studies have demonstrated that phytochemicals in flowers, such as flavonoids, phenolics, and alkaloids, play a critical role as natural reducing and stabilizing agents. For instance, *Jasminum nudiflorum* flower extract was effectively used for AgNP synthesis, yielding nanoparticles with antifungal and antioxidant

properties (Huq et al., 2022). Similarly, *Achillea biebersteinii* flowers produced AgNPs with significant anti-angiogenic potential in vascular tissue models (Gharanfoli et al., 2014). *Curcuma longa* flower extract was reported to yield highly uniform AgNPs (~5 nm) with strong antibacterial activity against *S. aureus* and *E. coli* (Rajak et al., 2023). Using *Syzygium samarangense* flowers, nanoparticles with excellent antimicrobial and dye degradation abilities were synthesized (Rafiq et al., 2022), while *Lantana camara* flower-mediated AgNPs also showed significant multifunctional bioactivity (Kuppusamy et al., 2016).

The use of *Datura metel* flower extract under ultrasound assistance facilitated the formation of 25–70 nm nanoparticles with enhanced antibacterial efficacy (Singh et al., 2017). *Bauhinia purpurea* flowers were utilized in another study to synthesize AgNPs that exhibited antimicrobial activity against clinical pathogens (Veerasamy et al., 2011). Likewise, AgNPs synthesized from *Nyctanthes arbortristis* flowers showed high antibacterial potency with negligible cytotoxicity to fibroblast cells, highlighting their biomedical relevance (Muthukrishnan et al., 2014). Other studies such as the one using *Bellevalia flexuosa* flower extract confirmed the antibacterial efficacy of the synthesized nanoparticles (Gültekin et al., 2020). Although not a flower, *Callisia fragrans* extract facilitated the synthesis of cytotoxic AgNPs with anticancer potential (Fatimah et al., 2023), demonstrating broader phytochemical capabilities.

Further, *Satureja hortensis* extract enabled the formation of silver-montmorillonite nanocomposites with antibacterial activity (Ghasemi et al., 2017), and *Malva sylvestris* flowers yielded AgNPs effective against *E. coli* and *S. aureus* (Ebrahimzadeh et al., 2021). *Salvia sclarea* (clary sage) flower extract also led to stable nanoparticles with excellent antimicrobial performance (Bibi et al., 2024). In addition, *Mangifera indica* (mango) flower-mediated AgNPs demonstrated bactericidal potential, with consistent results from spectral and morphological analyses (Raza et al., 2020). *Hemigraphis colorata* flower extract was found to be another effective source for synthesizing biologically active AgNPs (Bora & Debnath, 2021).

AgNPs synthesized from *Dillenia indica* flower extract showed strong antioxidant and antibacterial performance (Islam et al., 2024), while *Fritillaria* flowers yielded nanoparticles with substantial antimicrobial effects (Hemmati et al., 2019). Similarly, *Wedelia urticifolia* flower extract was employed to produce AgNPs with demonstrated activity against both Gram-positive and Gram-negative bacteria (Behravan et al., 2019). *Aerva lanata* flowers enabled the synthesis of multifaceted AgNPs with potential for varied biomedical applications (Kanniah et al., 2020), and repeated studies on *Nyctanthes arbortristis* reinforced its value in producing biocompatible antibacterial nanoparticles (Muthukrishnan et al., 2014).

Collectively, these studies affirm that flower extracts are a potent resource for green synthesis

of AgNPs, not only offering an environmentally benign synthesis route but also producing nanoparticles with diverse applications, particularly in antimicrobial therapy, catalysis, and nanomedicine. Variations in particle size, morphology, and bioactivity among different flower species further support the need for comprehensive studies to optimize plant-mediated nanoparticle synthesis for specific applications.

Table 1 Summary of the State-of-the-art

Reference	Method	Technology	Components	Results	Strength	Limitations
Huq et al. (2022)	Green synthesis	UV-Vis, FTIR, SEM	Jasminum nudiflorum flower extract	Antibacterial and antioxidant AgNPs	Eco-friendly and effective	Limited to in vitro analysis
Gharanfoli et al. (2014)	Green synthesis	UV-Vis, TEM, XRD	Achillea biebersteinii flower extract	AgNPs with anti-angiogenic effects	Potential in cancer therapy	Clinical trials not performed
Rajak et al. (2023)	Green synthesis	UV-Vis, XRD, HR-TEM	Curcuma longa flower extract	Homogeneous, spherical AgNPs (~5 nm) with antibacterial activity	Detailed characterization; potential medical applications	In vivo studies not conducted
Rafiq et al. (2022)	Green synthesis	UV-Vis, FTIR, SEM	Syzygium samarangense flower extract	AgNPs with antimicrobial and dye degradation capabilities	Environmental remediation potential	Long-term environmental impact not studied
Kuppusamy et al. (2016)	Review	Literature analysis	Multiple plant derivatives	Overview of biosynthesis methods and pharmacological applications	Broad coverage of plant-based nanoparticle synthesis	Lacks experimental validation
Singh et al. (2017)	Ultrasound-assisted green synthesis	UV-Vis, SEM	Datura metel flower extract	AgNPs with enhanced antibacterial activity	Improved synthesis efficiency	Requires ultrasonic equipment
Veerasamy et al. (2011)	Green synthesis	UV-Vis, TEM	Bauhinia purpurea flower extract	AgNPs with antimicrobial properties	Simple synthesis method	Limited characterization techniques
Muthukrishnan et al. (2014)	Green synthesis	UV-Vis, SEM	Nyctanthes arbortristis flower extract	Biocompatible AgNPs with antibacterial activity	Non-toxic synthesis approach	In vivo efficacy not evaluated

Gültekin et al. (2020)	Green synthesis	UV-Vis, FTIR, SEM	Bellevalia flexuosa flower extract	AgNPs with effective antibacterial activity	Plant-based synthesis method	Comparative studies lacking
Fatimah et al. (2023)	Green synthesis	UV-Vis, FTIR, SEM	Callisia fragrans flower extract	AgNPs with anticancer activity	Potential in cancer treatment	Specificity towards cancer cells not detailed
Ghasemi et al. (2017)	Green synthesis	UV-Vis, FTIR, SEM	Satureja hortensis flower extract	AgNP-montmorillonite nanocomposite with antimicrobial properties	Hybrid material with enhanced activity	Scalability not addressed
Ebrahimzadeh et al. (2021)	Green synthesis	UV-Vis, FTIR, SEM	Malva sylvestris flower extract	AgNPs effective against pathogens	Good antimicrobial activity	In vivo studies not conducted
Bibi et al. (2024)	Green synthesis	UV-Vis, FTIR, SEM	Salvia sclarea flower extract	Multifunctional AgNPs with antimicrobial and antioxidant activities	Dual functionality	Early-stage testing; clinical relevance unknown
Raza et al. (2020)	Green synthesis	UV-Vis, SEM	Mangifera indica flower extract	Bactericidal AgNPs	Consistent synthesis results	Toxicity studies not performed
Bora & Debnath (2021)	Green synthesis	UV-Vis, FTIR, SEM	Hemigraphis colorata flower extract	Biologically active AgNPs	Promising initial results	Application data lacking
Islam et al. (2024)	Green synthesis	UV-Vis, FTIR, SEM	Dillenia indica flower extract	AgNPs with strong bioactivity	Effective performance	Validation beyond lab scale needed
Hemmati et al. (2019)	Green synthesis	UV-Vis, SEM	Fritillaria flower extract	AgNPs with substantial antimicrobial effects	Effective nanoparticles	Mechanistic studies not performed
Behravan et al. (2019)	Green synthesis	UV-Vis, FTIR, SEM	Wedelia urticifolia flower extract	AgNPs with broad-spectrum activity	Effective synthesis method	Characterization limited
Kanniah et al. (2020)	Green synthesis	UV-Vis, FTIR, SEM	Aerva lanata flower extract	AgNPs with biomedical potential	Multiple applications	Preclinical studies needed
Acar et al. (2023)	Microwave-assisted green synthesis	UV-Vis, FTIR, SEM, TEM	Helichrysum arenarium flower extract	AgNPs with antibacterial and anticancer properties	Rapid synthesis with biomedical applications	Requires specialized equipment; scalability not assessed

Abdussalam-Mohammed et al. (2023)	Green synthesis	UV-Vis, FTIR, SEM	Teucrium apollinis extract	Stable AgNPs with significant antibacterial activity	Eco-friendly approach with good stability	Limited to in vitro studies
Alzubaidi et al. (2023)	Green synthesis	UV-Vis, FTIR, SEM, TEM	Calotropis procera flower extract	AgNPs with enhanced biomimetic attributes	Biogenic synthesis with potential biomedical applications	In vivo efficacy not evaluated
Khan et al. (2024)	Green synthesis	UV-Vis, XRD, TEM	Rubus fruticosus extract	AgNPs effective against phytopathogens	Potential in agricultural disease management	Field trials not conducted
Rehman et al. (2023)	Green synthesis	UV-Vis, FTIR, SEM	Azadirachta indica seeds extract	AgNPs with anti-diabetic activity	Demonstrated in vitro and in vivo efficacy	Long-term toxicity studies needed
Rabbi et al. (2023)	Green synthesis	UV-Vis, FTIR, SEM	Sterculia diversifolia stem bark extract	AgNPs with synergistic antibacterial effects	Potential for combined antimicrobial therapies	Specific mechanisms of synergy not explored
Asif et al. (2024)	Green synthesis	UV-Vis, FTIR, SEM, TEM	Tomato flower waste extract	Ag/Ag_2O nanoparticles with antibacterial and antitumoral potentials	Utilization of waste materials; dual functionality	Stability over time not assessed
Shahzadi et al. (2025)	Review	Literature analysis	Various plant extracts	Overview of green synthesis methods and applications	Comprehensive synthesis of current knowledge	Does not present new experimental data
Farooq et al. (2023)	Green synthesis	UV-Vis, FTIR, SEM	Various plant extracts	AgNPs with antibacterial, anticancer, and water treatment applications	Broad applicability across fields	Specific plant sources not detailed
George et al. (2023)	Green synthesis	UV-Vis, FTIR, SEM	Ophiocoma scolopendrina extract	AgNPs with antibacterial, antioxidant, and catalytic properties	Multifunctional applications	Specificity towards pathogens not detailed

Inference from the state-of-the-art

In this section, the statistics of the methods adopted, the technology used and the plant components employed in the synthesis of the synthesis of Nanoparticles from flower extracts is presented.

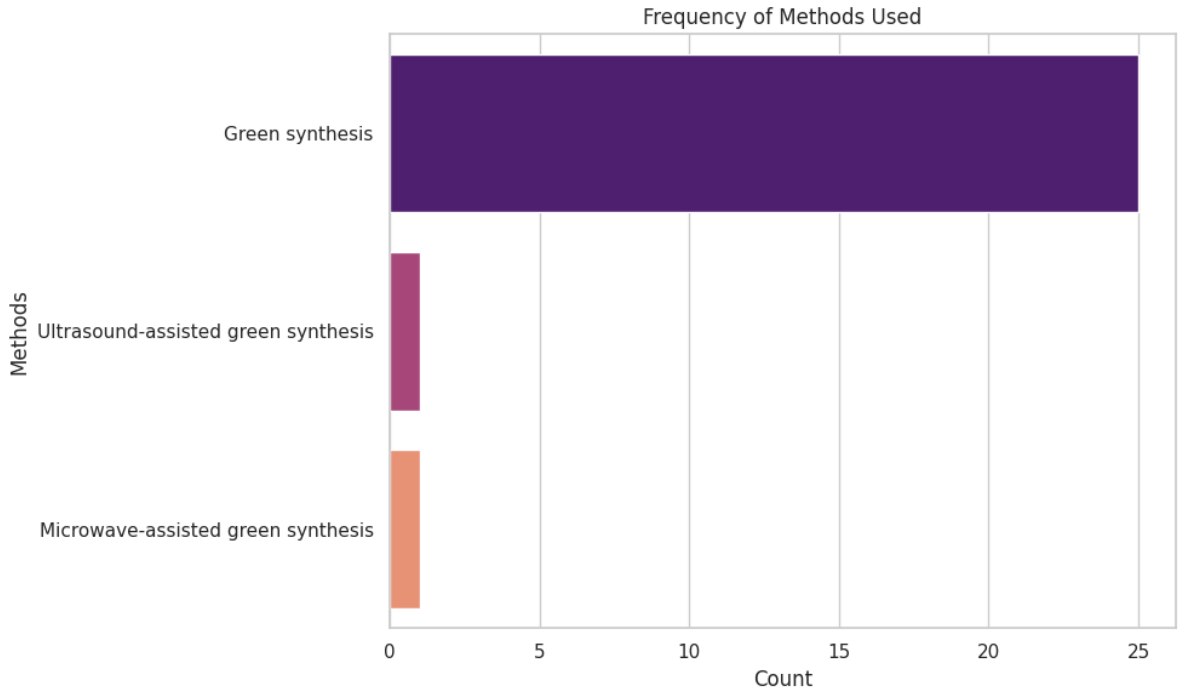

Figure 1 Distribution of Methods Used

Figure 1 shows the frequency of methods used in the synthesis of silver Nanoparticles from flower extracts. Based on the figure, it can be observed that the green synthesis method is widely used in the synthesis process. Other methods adopted include the ultrasound and microwave assisted green synthesis method.

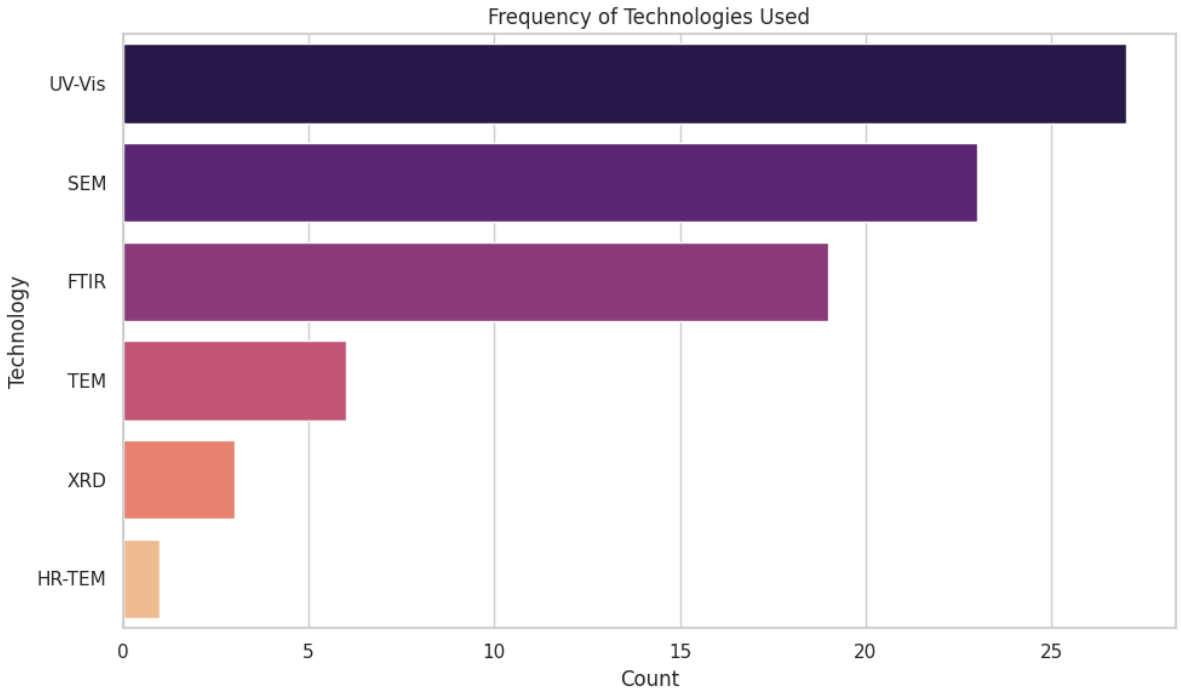

Figure 2 Distribution of Technology Used

Figure 2 depict the frequency of the technologies used in the synthesis of the silver Nanoparticles from flower extracts. Based on the figure, it is evident that UV-Vis, SEM and FTIR are frequently adopted in the synthesis of silver Nanoparticles from flower extracts. Other technologies used include TEM, XRD and HR-TEM.

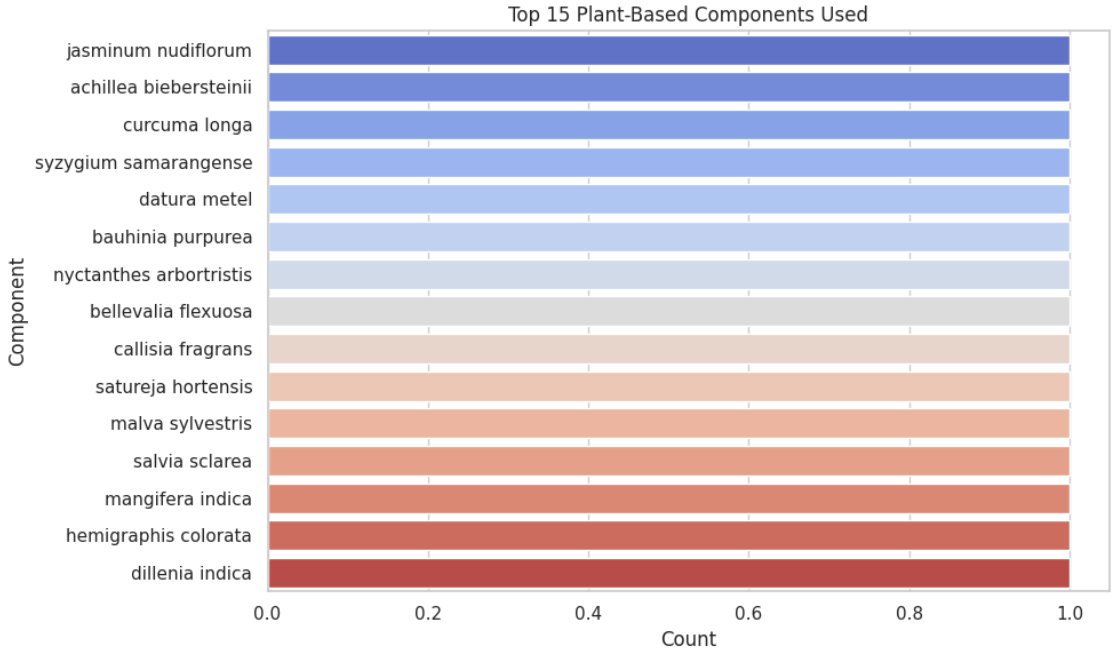

Figure 3 Distribution of plant components used

Figure 3 shows the distribution of plant components used in the synthesis of silver Nanoparticles from flower extracts with various components having equal distributions across various methods and technologies used in the process.

Taxonomy of Flower Extract

The taxonomy of silver nanoparticles (AgNPs) synthesized using flower extracts can be organized into four main categories: the biological source, synthesis approaches, characterization methods, and practical applications. This structured framework offers a thorough understanding of the green synthesis process and highlights its relevance in both nanotechnology and biomedical fields. The taxonomy is presented is depicted in figure 1 below.

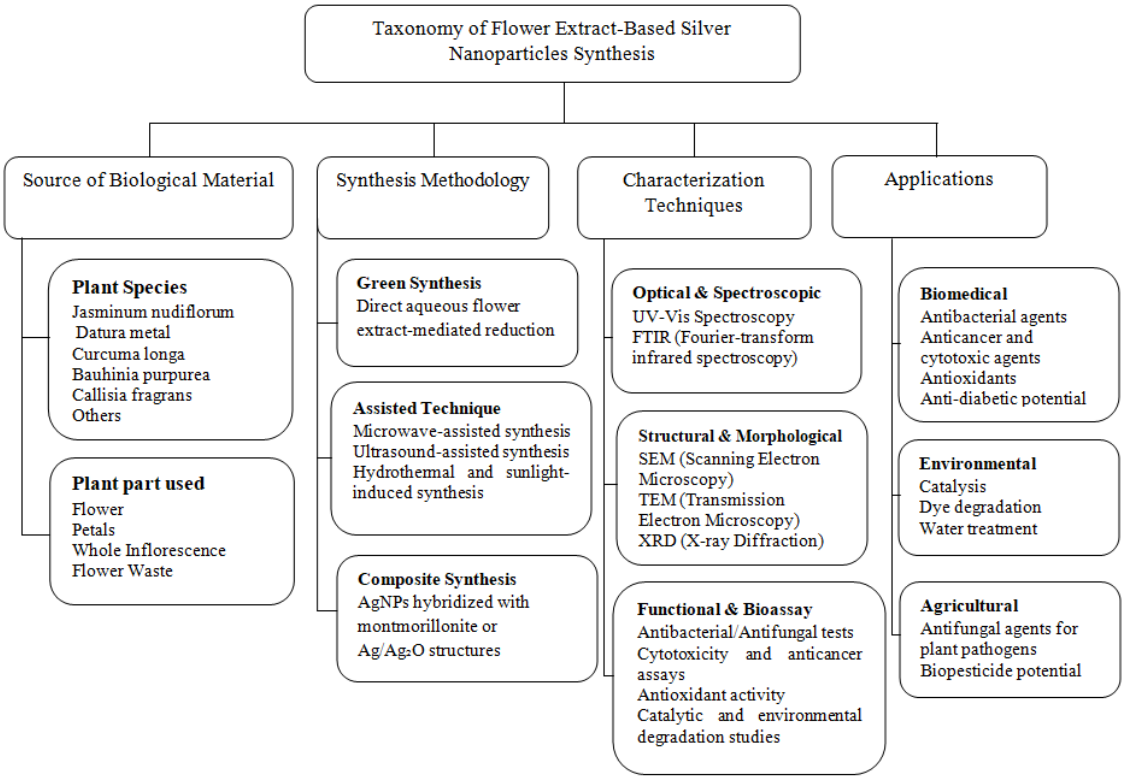

Figure 1 Taxonomy of Flower Extract

Source of Biological Material

The primary tier of the taxonomy centers on the specific plant species used in the synthesis of silver nanoparticles. Flowers such as *Jasminum nudiflorum*, *Datura metel*, *Curcuma longa*, and *Bauhinia purpurea* are commonly selected for their rich content of bioactive molecules, including flavonoids, terpenoids, phenols, and alkaloids, which actively reduce silver ions to form AgNPs (Veerasamy et al., 2011; Rajak et al., 2023). These phytochemicals act dually as reducing and stabilizing agents, promoting an environmentally friendly and economically viable synthesis method. Additionally, the taxonomy encompasses composite synthesis approaches, where AgNPs are integrated with substances like montmorillonite or Ag/Ag_2O to enhance particle stability and broaden functional applications (Ghasemi et al., 2017; Asif et al., 2024).

Synthesis Methods

Synthesis methods are broadly classified into three categories: green synthesis, assisted techniques, and composite synthesis. Green synthesis relies on the direct reduction of silver nitrate using flower extracts, without the need for additional chemical agents or stabilizers. This approach is favored for its eco-friendly nature and straightforward process (Fatimah et al., 2023; Islam et al., 2024). Assisted techniques, such as ultrasound- and microwave-assisted synthesis have been developed to enhance nanoparticle yield and uniformity (Singh et al., 2017; Acar et al., 2023). These advanced methods accelerate reaction rates and shorten synthesis time, though they typically require specialized equipment.

Characterization Techniques

This category is further divided into two main subgroups: optical and spectroscopic analyses, and functional bioassays. Commonly used characterization techniques include UV-Visible spectroscopy, Fourier-transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and X-ray diffraction (XRD). These methods are essential for evaluating the size, morphology, surface charge, and elemental composition of silver nanoparticles (Alzubaidi et al., 2023; Huq et al., 2022). Functional bioassays, on the other hand, are used to measure the biological efficacy of AgNPs, examining properties such as antibacterial, antifungal, cytotoxic, and antioxidant activity (Behravan et al., 2019; Bibi et al., 2024). Such evaluations are crucial in confirming the therapeutic potential and translational value of the synthesized nanoparticles.

Applications

Applications of flower-mediated silver nanoparticles are generally divided into biomedical and environmental sectors. In biomedicine, these AgNPs have demonstrated strong antibacterial, antioxidant, anticancer, and anti-diabetic effects (Ebrahimzadeh et al., 2021; Abdussalam-Mohammed et al., 2023), making them suitable for uses such as drug delivery systems, wound healing agents, and antimicrobial surface coatings. In the environmental domain, AgNPs are employed in catalysis, dye degradation, and water purification, where they function as effective catalysts or adsorbents for breaking down organic contaminants (Rafiq et al., 2022; Farooq et al., 2023). The diverse functionality of these nanoparticles highlights their potential for sustainable applications in both healthcare and environmental remediation.

Challenges and Solutions

The utilization of flower extracts for the green synthesis of nanoparticles represents a sustainable and environmentally friendly alternative to traditional chemical and physical synthesis techniques. Despite its advantages, this method faces several obstacles that hinder its broader application. A major limitation is that most current research remains restricted to in vitro studies or small-scale laboratory experiments. This lack of in vivo testing and clinical validation poses a barrier to translating these findings into practical, real-world biomedical or industrial applications. Moving forward, it is essential for future investigations to incorporate animal models and clinical trials to establish the efficacy and safety of these nanoparticles in more complex biological systems. Another pressing issue is the limited characterization of the synthesized nanoparticles. Many investigations rely on only a few analytical methods, which may not provide a complete profile of key nanoparticle attributes such as size distribution, surface morphology, charge, and crystal structure. This shortfall can be addressed by employing a broader set of characterization techniques, including Fourier-transform infrared spectroscopy (FTIR), transmission electron microscopy (TEM), X-ray diffraction (XRD), dynamic light scattering (DLS), and zeta potential

analysis. These tools collectively offer a more detailed and accurate understanding of nanoparticle properties.

A lack of standardization in synthesis protocols also contributes to inconsistencies in experimental outcomes. Differences in methodology across studies make it difficult to compare results or replicate findings. To enhance reproducibility, it is crucial to establish standardized operating procedures (SOPs) and apply statistical modeling tools such as response surface methodology (RSM) to fine-tune synthesis parameters. These approaches can help define optimal conditions for producing nanoparticles with uniform characteristics. Scaling up the green synthesis process presents yet another challenge. While suitable for small-scale production, traditional methods are often inefficient when applied at an industrial scale. This issue could be mitigated by integrating advanced techniques such as microwave-assisted or ultrasound-assisted synthesis. These methods not only accelerate the reaction process but also support large-scale production without compromising nanoparticle quality. Additionally, the long-term stability and shelf-life of biologically synthesized nanoparticles remain areas of concern. Their practical use is often limited by poor stability under varying storage conditions. This challenge can be tackled by using natural capping agents during synthesis and performing accelerated stability studies under diverse environmental conditions to ensure the durability of the nanoparticles. Toxicological and biocompatibility assessments are also underexplored. Although green synthesis is generally perceived as safer, comprehensive evaluations of cytotoxicity, genotoxicity, and the effects of prolonged exposure—both in vitro and in vivo—are necessary to confirm the biosafety of these nanoparticles. Furthermore, the mechanisms behind the biological activity of flower-derived nanoparticles are not yet fully understood. A deeper understanding of how these particles interact with cells and molecular pathways is essential for optimizing their design for specific therapeutic or environmental functions. Techniques from molecular biology, such as transcriptomic and proteomic analyses, could provide valuable insights into these mechanisms and guide future nanoparticle engineering.

Finally, the absence of control or comparative studies in much of the current literature hampers the assessment of the true effectiveness of green-synthesized nanoparticles. Future research should include benchmarking against chemically synthesized or alternative biologically synthesized nanoparticles to identify relative advantages, limitations, and areas for improvement. In conclusion, while green synthesis using flower extracts offers significant promise, addressing these limitations through more rigorous, standardized, and translational research is vital. Doing so will pave the way for the broader adoption of these nanoparticles in biomedical, agricultural, and environmental applications.

Conclusion

Green synthesis of silver nanoparticles (AgNPs) using flower extracts offers an environmentally responsible and sustainable alternative to

traditional chemical and physical fabrication techniques. This review underscores the remarkable capabilities of various floral species including *Dillenia indica*, *Curcuma longa*, and *Malva sylvestris* in generating AgNPs that exhibit strong antimicrobial, antioxidant, and catalytic effects. The presence of naturally occurring bioactive constituents such as phenolics, flavonoids, and terpenoids plays a dual role in both reducing silver ions and stabilizing the resulting nanoparticles, allowing for controlled synthesis in terms of particle size and shape. Modern approaches, including microwave- and ultrasound-assisted methods, further optimize the synthesis process for greater efficiency and scalability. Structural and functional validation of the nanoparticles is achieved through techniques like UV-Vis spectroscopy, FTIR, SEM, and TEM, while their practical effectiveness is confirmed through biomedical and environmental bioassays. Despite these advancements, challenges remain, including the need for standardized protocols, large-scale production feasibility, and comprehensive in vivo studies to assess biosafety and long-term effects. Future research should focus on **Optimizing synthesis parameters** using statistical modeling (e.g., Response Surface Methodology) to ensure reproducibility, **Expanding in vivo and clinical trials** to evaluate therapeutic potential and toxicity, **Exploring hybrid nanocomposites** to enhance functionality for targeted applications and **Assessing environmental impact** to ensure sustainability in large-scale deployment. Bridging the current research gaps will enable the broader utilization of flower-derived silver nanoparticles (AgNPs) in diverse fields such as medicine, agriculture, and environmental cleanup, contributing meaningfully to global sustainability objectives. Realizing this potential will require strong interdisciplinary collaboration, fostering innovation at the intersection of nanotechnology, biology, and environmental science.

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