



**GREEN SYNTHESIS OF METALLIC NANOPARTICLES BY
ACTINODAPHNE MADRASPATANA: A CRITICAL REVIEW**

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ABSTRACT

The production of nanoparticles from plant species is of great interest now a days as they exhibit important characteristic features of possessing antimicrobial and anticancer activities. The review study focuses on a green synthesis of metallic nanoparticles which avoid the usage of hazardous substances, reducing agents, or chemically synthesized protecting substances. This process utilizes accessible components found in nature. This environmentally friendly method of synthesizing metallic nanoparticles has gained popularity based on its non-toxic nature, cost-effectiveness, and ecological benefits. In this particular study, *Actinodaphne madraspatana*, a plant belonging to the *Lauraceae* family and native to India, is used as both a reducing agent and a stabilizing agent in metallic nanoparticle synthesis. The traditional treatment carried out by the leaves of this plant are mental illness, diabetes, and wounds. This review aims to provide a comprehensive overview of the synthesis of metallic nanoparticles by *Actinodaphne madraspatana* and their diverse therapeutic applications. The characterization of metallic nanoparticles produced by this plant help in understanding the properties, probable applications and behavior of the nanoparticles. The review also explores the morphological and

phytochemical studies of the *Actinodaphne madraspatana* plant. Therefore, this study may provide the high production and use of nanoparticles from the *Actinodaphne madraspatana* plant to treat severe diseases.

Keywords: metallic nanoparticles, green synthesis, silver, gold, iron-oxide, palladium, zinc-oxide

INTRODUCTION

The study of Nanotechnology is altering any matter at the nanoscale to create novel and distinctive materials. With the capacity to reduce material prices, minimize energy usage, be incredibly smaller, and have a significant ratio of surface to volume, nanotechnology can be cost-effective [1]. In terms of biological qualities, catalytic activity, optical absorption, thermal and electrical conductivity, mechanical properties, and melting point, nanoparticles differ from bulk materials with the same chemical composition in terms of both their chemical and physical features [2].

Using natural materials to convert metallic ions into nanoparticles offers an environmentally beneficial approach to nanoparticle synthesis [3]. The synthesis can be achieved through various techniques, including chemical, physical, and biological methods. Chemical processes including the sol-gel method, chemical reduction procedures, and co-precipitation are utilized to create nanoparticles [4]. Thermal breakdown, laser irradiation,

ultrasonication, ball milling, and electrolysis are the physical processes utilized to synthesize nanoparticles [5]. The biological process identified as biofabrication is used to synthesize nanoparticles. This process uses microorganisms such as bacteria, fungi, yeast, virus, microalgae, macroalgae, and plant biomass/extract [6]. Nanoparticles are broadly used in industries, including biomedicine, agriculture, drug delivery, catalysis, and wastewater treatment (Figure 1) [7]. Compared to other biological sources, plant biomass/extract has certain significant advantages in the production of nanoparticles over other tiny substances [8]. Plants have the distinctive potential for the production of metallic nanoparticles by various biomolecules present in their biomass. These biomolecules include amino acids, enzymes, proteins, polysaccharides, organic acids, and vitamins such as citrate. Each of these biomolecules can perform a specific function in the stabilization and synthesis of metallic nanoparticles [9].

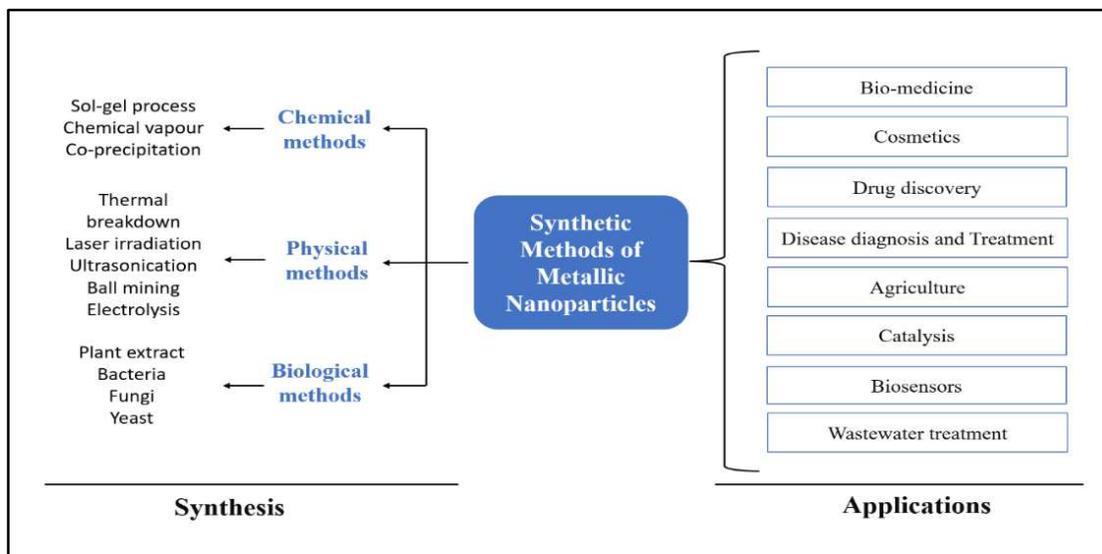


Figure 1: Nanoparticles- Methods with their Applications

The primary step in the nanoparticles formation involves reducing metal complexes to obtain metal colloidal dispersion. The green synthetic method is required to convert the metallic precursors into nanoparticles [10]. Green or natural materials, including plant and microbial extracts, have garnered significant intensity in the field of nanoparticle synthesis [11]. One method entails mixing extracts of plants with metallic compound solutions for the required nanoparticle production. The non-biological applications include photocatalysis and reduction properties whereas the biological applications include antiviral, bactericidal, fungicidal, anti-inflammatory, anti-carcinogenic, and anti-oxidant capabilities [12]. Biomolecules serve in-situ reducing and capping agents that stabilize the nanoparticles by reducing metallic salts from an oxidation state (positive) to a zero-oxidation state. The

monolayer is formed surrounding the nanoparticle and the agglomeration prevention that occurs when nanoparticles interact chemically and physically. Maintaining the surface energy of nanoparticles is essential for ensuring their durability and efficacy. Agglomeration should avoid the distinctive qualities and reactivity of the nanoparticles preserved with correct surface energy control [13]. Several studies had centered on distinct nanoparticle synthesis including silver, gold, palladium, iron-oxide, and zinc-oxide nanoparticles [14].

Morphology of *Actinodaphne madraspatana*

The *Actinodaphne madraspatana* plant is a species of the *Lauraceae* family and is endemic to India. It is a widespread, standard-size evergreen tree that grows on the Rock Hill slopes at higher altitudes [15]. The leaves are coriaceous, lanceolate,

oblanceolate, or elliptic, and are 4-6 in a whorl and 10–30 cm long. Flowers are dioecious, brownish-yellowish, and borne in dense clusters in the axillary or lateral axils. The female flowers are umbellate, while the male flowers are in groups and produce ellipsoidal berries as their fruits [16].

Medicinal uses

Traditional uses for the plant's leaves include treating diabetes and using them to treat insanity, erratic behavior, and wounds. The plant is a vitamin A precursor. According to reports, the flowers are liable to treat mania and unstable behavior [17]. *Actinodaphne madraspatana* leaves with ethanol extract possess antidiabetic and anti-inflammatory properties, and further research is necessary to isolate and characterize them. The active phytoconstituents available from the leaves of the plant are liable for anti-inflammatory, antioxidant, and antidiabetic efficacy and are tested in in-vitro [18]. Plant-based remedies have been studied for their wound-healing properties, and numerous plant species have been described to show significant wound-healing activity [19].

Phytochemicals analysis

Recent research on the phytoconstituents of *Actinodaphne madraspatana* Bedd extracts confirmed the substances present in the plant leaves such as tannins, flavonoids, saponins, triterpenoids, steroids, alkaloids, glycosides, and carbohydrates [20]. These active

polyphenolic compounds have therapeutic effects to being reliable stabilizers and reductants for nanoparticle synthesis. Green chemistry principles are satisfied by the practicality, availability, and biocompatibility of these active phenolic chemicals found in *Actinodaphne madraspatana* Bedd leaves, which motivates us to investigate the effectiveness of plant extract in nanoparticle formation. In a process of nanoparticle formation, the phytoconstituents found in the *Actinodaphne madraspatana* leaves extract served as reducing and protective agents [21].

A green approach for the metallic nanoparticles synthesis utilizing plant extract

Plants are considered the low-maintenance, cost-effective, and chemical factories of nature. The synthesis of nanoparticles by plant extract is beneficial including easy availability, eco-friendly relationship, zero contamination, and higher reduction potential [22]. Since even minute amounts of these heavy metal traces can be adverse at low concentrations, plants have shown exceptional potential in detoxifying and accumulating heavy metals. Compared to other biological synthesis procedures carried out by microbes, the creation of nanoparticles by plant extract has some advantages [23]. A plant extract has the benefit of conserving microbiological

cultures, allowing nanoparticle synthesis with higher capacity than other biologically synthetic methods [24].

Phytochemicals present in fruit, leaves, stems, and roots are widely utilized for the green synthesis of nanoparticles. Plant parts are primarily washed and heated in distilled water for nanoparticle formation. After squeezing, filtering, and adding respective solutions, the solution color gradually changes, revealing the nanoparticle formation (**Figure 2**) [25]. Plant extracts are ecological and affordable, eliminating base groups as intermediate during synthetic processes. The polyols, polyphenols, and

terpenoids are phytochemicals found in plant extract resulting in the bioreduction of metallic ions. Using natural biomolecules as reducing agents increases synthesized nanoparticle's biocompatibility and potential biomedical applications. Nanoparticles are distinguished primarily by dispersity, shape, size, and surface area [26]. The respective methods used to characterize nanoparticles are UV--visible spectrophotometry, Fourier transform infrared spectroscopy (FT-IR), X-ray diffraction (XRD), Transmission electron microscopy (TEM), and Scanning electron microscopy (SEM) [27].

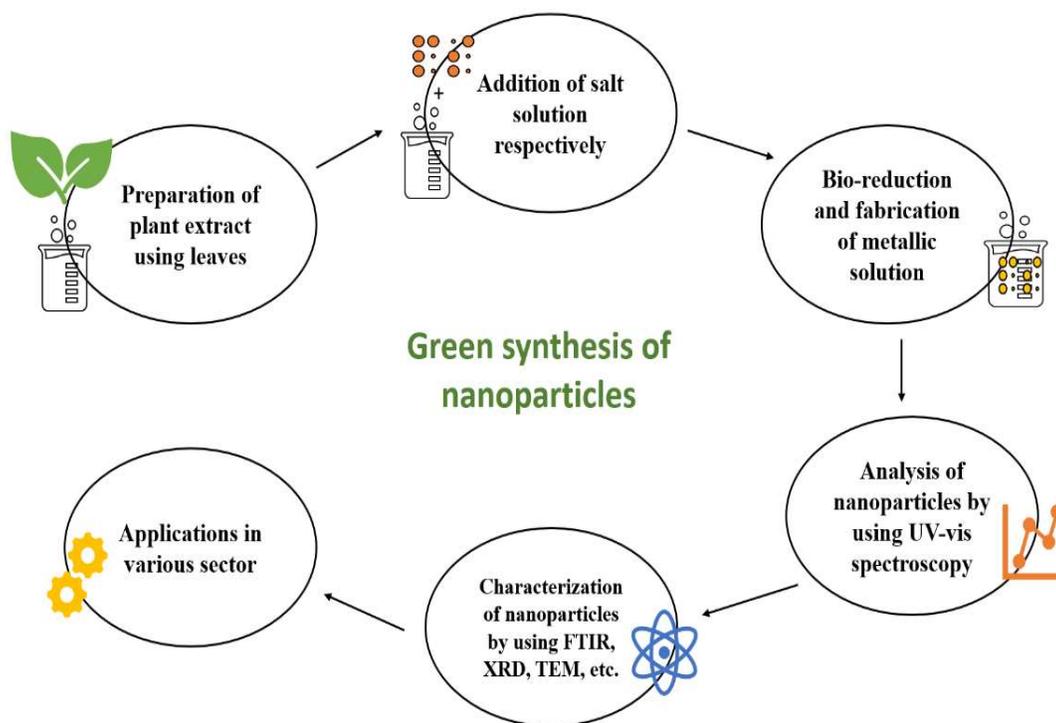


Figure 2: Flowchart for the synthetic route of nanoparticle synthesis, characterization with applications

Synthesized nanoparticles by plant leaves of *Actinodaphne madraspatana*

A. Silver nanoparticles

Silver nanoparticles (AgNPs) have appeared as highly versatile nanomaterials with diverse applications in sectors ranging from healthcare and electronics to environmental remediation and agriculture. The silver nanoparticle synthesis primarily involves a solution of silver metal ions and a biological agent capable of reduction and stabilization of the nanoparticles through the reaction of biomolecules found in plant components such as alkaloids, amino acids, polysaccharides, proteins, phenolics, saponins, terpenes, and vitamins [28]. Previous research studies had disclosed that the *Actinodaphne madraspatana* leaf extract can be combined with a 1mM AgNO₃ solution to facilitate the silver nanoparticle formation. The presence of silver nanoparticles is always revealed by the observable color change, and their distinct characteristics can be investigated further based on their sizes, shapes, surface areas, and dispersion. The silver nanoparticles (AM-AgNPs) formation from the extract of leaves was shown by the intensity increase of the surface plasmon resonance (SPR) band at a wavelength of 410 nm, providing evidence that the AgNO₃ solution is being converted into silver nanoparticles (AM-AgNPs). Analysis of the *Actinodaphne madraspatana* Bedd leaf extract using FTIR

spectroscopy revealed significant peaks at 3288 cm⁻¹, 1592 cm⁻¹, 1372 cm⁻¹, 1032 cm⁻¹, and 822 cm⁻¹, respectively. Furthermore, XRD investigation of the AM-AgNPs diffraction pattern shows peaks at 38, 44, 64, and 77, corresponding to the (111), (200), (220), and (311) lattice planes. Earlier research has indicated the AgNPs size decreases from 60 to 20 nm with an increase in pH from 6 to 12. Additionally, the alkaline pH of the extract of *Actinodaphne madraspatana* Bedd accelerates the silver ions reduction to AgNPs at a faster rate. Moreover, these environmentally friendly and catalytically active AM-AgNPs can be utilized for investigating the degradation of organic pollutants, such as textile dyes, present in industrial effluents [29].

B. Gold nanoparticles

Gold nanoparticles (AuNPs) have garnered significant attention for having distinct properties, making them highly versatile in various applications such as high biocompatibility, medicine, tunable surface plasmon resonance, low toxicity, strong scattering, absorption, etc. [30]. The AuNPs synthesis using *Actinodaphne madraspatana* leaf extract involves the interaction of specific chemical compounds available in the leaf extract which results in gold ions reduction and nanoparticle formation. As per the earlier studies, the gold ions reduction to AuNPs is achieved within 48 hours by the extract which

contains terpenoids are liable for this reaction. The mixture color turned pink on adding 1mM $\text{HAuCl}_4 \cdot 3\text{H}_2\text{O}$ to the leaf extract, indicating the AM-AuNPs production. The UV-Vis spectra revealed a steady increase in the intensities of the surface plasmon resonance (SPR) band at 530 nm, shifting from 558 to 530 nm. The Fourier-transform infrared (FTIR) spectra of the *Actinodaphne madraspatna* Bedd leaf extract exhibited significant peaks at 3336 cm^{-1} , 1602 cm^{-1} , 1383 cm^{-1} , and 1022 cm^{-1} , suggesting the involved functional groups are present in the reduction and stabilization of AuNPs. X-ray diffraction (XRD) analysis confirmed the crystalline nature of the synthesized AuNPs, with diffraction peaks corresponding to the (111), (200), (220), and (311) lattice planes of the face-centered cubic (fcc) structure. Previous research stated that the average size of synthesized AM-AuNPs particles decreased from 80-20 nm. The shape of the AM-AuNPs was observed to be polyhedral, and the selected area electron diffraction (SAED) pattern exhibited bright spots in concentric diffraction rings, indicating their crystalline nature. The synthesized AM-AuNPs demonstrate potential applications in environmental remediation, particularly for polluted water treatment. Their unique properties and characteristics make them appropriate for various fields, including biocompatibility, medicine, biology, and

optical applications. The gold nanoparticle synthesis by *Actinodaphne madraspatana* leaf extract offers a sustainable and eco-friendly approach to obtaining AuNPs with tunable properties. These nanoparticles hold great promise for various applications, including environmental remediation and advanced technological applications [31].

C. Palladium nanoparticles

Palladium is a silvery-white expensive metal having high density. Palladium nanoparticles (PdNPs) have gained increasing demand in past years based on their wide-ranging applications in catalysis, fuel cells, hydrogen storage, sensors, and the active membranes preparation. Furthermore, PdNPs are particularly valued in catalysis due to their elevated surface energy, high surface-to-volume ratio, lower coordination numbers, and increased surface atom availability. The factors contribute to enhanced catalytic properties [32]. Previous studies have revealed that *Actinodaphne madraspatana* Bedd (AMB) leaves can synthesize PdNPs. The introduction of a 1mM Pd (OAc)₂ solution to the extract of leaves leads to a color change, indicating the formation of Pd nanoparticles. The absorption peak of the synthesized nanoparticles is observed at 400 nm with a broad continuous absorption band in the UV-visible range between 200 to 700 nm. FTIR spectra analysis of the AM-PdNPs reveals significant peaks at 3288, 1592,

1372, 1032, and 822 cm^{-1} , specifying the presence of specific functional groups as reducing and stabilizing of PdNPs. X-ray diffraction (XRD) patterns exhibit peaks of diffraction at 40.6, 46.8, and 68.1, corresponding to the (111), (200), and (220) reflection planes, respectively. TEM images provide particle size histograms, demonstrating that the AM-PdNPs synthesis are well-dispersed and range in size from 6 to 22 nm, with an average particle size of 13 nm. The PdNPs exhibit a variety of shapes, including spherical, quasi-spherical, and twinned crystals, displaying

monodispersity. These synthesized PdNPs have proven to be effective and alternative nanocatalysts for the environmental remediation of toxic substances and organic pollutants found in industrial wastewater. Additionally, they show potential applications in medicine and sensors. Their unique properties make them valuable in diverse fields, highlighting their versatility and promising role in addressing environmental and healthcare challenges [33].

Table 1: Green synthesized nanoparticles properties and applications

Year	Material Precursor	UV intensity (nm)	Particle Size/ Shape	Applications	References
2017	Silver (AM-AgNPs)	410	20-60 nm/ Spherical	Anti-cancer, catalytic activity	[42]
2020	Gold (AM-AuNPs)	400	20-80 nm/ Polyhedral	Antimicrobial activity, environmental remediation of polluted water	[45]
2017	Palladium (AM-PdNPs)	400	13 nm/ Spherical	Catalysis, Bio-sensors, remediation of wastewater	[48]
2017	Iron oxide (AM-FeNPs)	280	20 nm/ Spherical	Phyto-catalytic and anti-microbial activity	[49]
2021	Zinc (AM-ZnONPs)	355	18-68 nm/ wurtzite crystal	Photo-catalytic activity, and bio-remediation	[50]

D. Iron oxide nanoparticles

Iron oxide nanoparticles (FeONPs) have gained significant attention in materials research and biomedical fields based on their ultra-fine sizes, high surface-to-volume ratios, and biocompatibility. Various conventional methods, such as vacuum sputtering, aerosol, electrochemical synthesis, thermal decomposition, and

chemical processes utilized for FeONPs synthesis [34]. Previous research reveals that the reaction mixture of 0.1 M FeCl_3 nanoparticle solution with *Actinodaphne madraspatna* Bedd leaf aqueous extract results in a blackish-brown color, indicating the creation of FeONPs. The absorbance peak of ferric chloride (the iron precursor) is observed around 300 nm, with continuous

absorption in the visible range of 400 to 600 nm. The phenolic moieties present in the *Actinodaphne madraspatna* Bedd leaf extract contribute to the absorbance peak at 280 nm. FT-IR measurements have been conducted to regulate the function of phytoconstituents in the *Actinodaphne madraspatna* Bedd leaf extract in the production of AM-FeONPs. The extract of leaves displays significant peaks at 3422 cm^{-1} , 1645 cm^{-1} , 1404 cm^{-1} , and 1091 cm^{-1} . The absence of the zero-valent iron peak at $2\theta = 45^\circ$ further supports the successful synthesis of FeONPs. The synthesized AM-FeONPs exhibit an approximately spherical shape and 20 nm is the average particle of size. TEM images reveal that a thin organic layer is present surrounding the synthesized AM-FeONPs, acting as a layer of capping and ensuring the particles are well-separated. This highlights the phytoconstituent present in the *Actinodaphne madraspatna* leaf extract in providing a role of stability to the FeONPs [35].

E. Zinc oxide nanoparticles

Zinc oxide nanoparticles (ZnONPs) have garnered significant attention from researchers and scientists in recent times based on their numerous utilizations in the biomedical field, optics, and electronics. These nanoparticles possess unique properties, including a high binding energy excitation of 60 meV and a large bandgap of

3.37 eV, which contribute to their semiconducting characteristics such as high catalytic activity, wound healing, anti-inflammatory properties, and UV filtering capabilities. Consequently, they find extensive use in various cosmetic products, particularly in sunscreens. Additionally, ZnONPs have shown great potential in diverse applications in the biomedical field, including antifungal, antibacterial, anticancer, antidiabetic, and drug delivery activities [36]. To synthesize ZnONPs in a green and sustainable manner, a strategy employing the leaf extract of *Actinodaphne madraspatna* Bedd (AMB) has been employed. The reaction solution color changes confirm the formation of ZnO nanoparticles. The UV-Vis spectra of the ZnONPs synthesized in the presence of AMB extract reveal an absorbance peak at 355 nm. The FT-IR spectrum of the ZnONPs displays a characteristic peak at 416.62 cm^{-1} . Further studies on the optical properties of AM-ZnONPs indicate a reduction in the bandgap values within the range of 3.05 to 2.96 eV. TEM data provide insights into the crystal structure of the synthesized AM-ZnONPs, which exhibit a wurtzite crystal structure with crystallite sizes ranging from 18 nm to 68 nm. The observation is that the green-synthesized AM-ZnONPs, with their reduced bandgap, exhibit enhanced photocatalytic activity and

bioremediation capabilities, as evidenced by higher rate constants [37].

CONCLUSION

In this study, a simple, cost-effective synthesis of metallic nanoparticles by plant *Actinodaphne madraspatna* Bedd leaf extract was studied. The nanoparticles were distinguished with each other based on their size, shape, surface area, and dispersity. The presence of phytoconstituents such as proteins, phenols, tannins, flavonoids, saponins, triterpenoids, steroids, alkaloids, glycosides, and carbohydrates in the extract might be responsible for the synthesis of AuNPs, AgNPs, PdNPs, FeONPs, and ZnONPs. Additionally, plants had special chemicals that assist in synthesis and increasing the process rate. The green synthesis of nanoparticles using plants is a fascinating, rapidly expanding area of nanotechnology, and has a significant impact on the environment in the direction of sustainability. The synthesized nanoparticles have several applications in catalysis, bioengineering sciences, medicine, water treatment, bio-sensors, agriculture, cosmetics, and other biological domains. These biogenic nanoparticles can be employed in numerous ways to disinfect water for environmental remediation as well as in nano-weapons against phytopathogens. These synthesized nanoparticles may represent the future force of the biomedical industry in the drug delivery system.

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