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Research Article

Swietenia mahagoni leaf extract is used in the green synthesis and polyvinylpyrrolidone functionalisation of gold nanoparticles for improved biocompatibility.

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Abstract: Nanotechnology has revolutionized various industries, and gold nanoparticles (AuNPs) are particularly significant due to their biocompatibility and versatile applications. This study introduces a simple, environmentally friendly method for producing gold nanoparticles (AuNPs) using an aqueous leaf extract of *Swietenia Mahagoni*, motivated by the need for sustainable nanotechnology. Both a stabilizing capping layer for the expanding nanoparticles and a reducing agent for gold ions are functions of the phytoconstituents in the extract. For biomedical applications, the biosynthesized AuNPs were functionalized with polyvinylpyrrolidone (PVP) to further improve colloidal stability and biocompatibility. A thorough characterisation procedure verified that the synthesis and functionalization were successful. The creation of AuNPs was demonstrated by UV-visible spectroscopy via a pronounced surface plasmon resonance (SPR) absorption band. The face-centered cubic crystalline structure of the nanoparticles was confirmed by X-ray diffraction (XRD) investigation. Crucially, direct proof of the precise functional groups from *Swietenia Mahagoni* phytochemicals (such as phenolics and terpenoids) in charge of reduction and capping was supplied by Fourier-transform infrared (FTIR) spectroscopy. Further FTIR analysis verified that PVP effectively encapsulated the AuNPs. In order to create complex AuNPs, this study shows how to work in combination with biocompatible polymer functionalization and plant-mediated green synthesis. The process greatly aids in the creation of sustainable nanomaterials by utilizing renewable resources, removing harsh chemicals, and producing nanoparticles with improved stability appropriate for therapeutic and diagnostic uses.

Key Word: Plant extract, Gold nanoparticles, Green synthesis, Polyvinylpyrrolidone, *Swietenia mahagoni*

Abbreviations

PVP	Polyvinyl pyrrolidone
AuNPs	Gold nanoparticles
b-AuNPs	Biologically synthesized Gold nanoparticles
PVP-b-AuNPs	PVP-functionalized biologically synthesized Gold nanoparticles

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INTRODUCTION:

Nanoparticles, which are usually defined as particles up to 100 nm in size, can have new or substantially improved properties above their bulk material counterparts. These emergent characteristics are

primarily driven by changes in important attributes including morphology, size, and size distribution. [1]. The creation and uses of noble metal nanostructures have thus been the subject of much research. [2]. Due to its exceptional sustainability profile and particular

biological, physical, chemical, and environmental characteristics, the synthesis of nanoparticles (NPs) has attracted a lot of scientific research. [3-4]. Significantly, the size and form of nanoscale materials effect their physicochemical and spectroscopic characteristics. [5].

The burgeoning field of green synthesis research aims to develop environmentally benign methodologies for producing high-quality, commercially viable nanostructures [6]. This pursuit has engaged biologists, chemists, and materials scientists, particularly in the search for eco-friendly and economical routes for nanoparticle synthesis, representing a shift towards "greener" pathways for inorganic material production [7]. These objectives have spurred the investigation of novel techniques and materials aligned with the principles of "Green Chemistry" [8]. Specifically, "green synthesis" refers to the utilization of biological materials—such as plant extracts, microorganisms (bacteria, fungi), or algae—to produce nanoparticles like gold nanoparticles (AuNPs) under mild conditions, avoiding toxic reagents and harsh processes [9].

AuNPs are highly versatile nanostructures with broad applicability, largely attributable to their capacity for facile conjugation with diverse molecules, including drugs, oligonucleotides, and antibodies [10]. This synthesis approach offers inherent ecological sustainability by eliminating hazardous chemicals throughout the production process [11]. The significant attention devoted to AuNPs stems from their numerous valuable applications in medicine, diagnostics, and technology. Their chemical inertness and resistance to surface oxidation further enhance their utility in nanoscale devices and technologies [12-13]. Recent research has explored AuNPs in diverse shapes and structures, including dendrimer-like forms, nanorings, nanoplates, nanocubes, and nanoprisms [14]. Crucially, the characteristics of plant-extract-synthesized nanoparticles are known to be influenced by the extract source, owing to variations in the concentrations and combinations of organic reducing agents present in different plant materials [15]. Consequently, plant-based synthesis has evolved as a prominent green alternative to chemically assisted methods [16] the capability of plant extracts, bacteria, fungi, and other biological agents to synthesize AuNPs has been extensively studied [17].

This study employs aqueous leaf extracts of *Swietenia mahagoni*—a tropical tree rich in bioreducing phytochemicals—to demonstrate a rapid and inexpensive synthesis route for AuNPs [18]. *S. mahagoni* leaf extract represents a sustainable resource for producing bioactive compounds and nanoparticles. By highlighting its antimicrobial properties, efficacy in nanoparticle formation, and medicinal significance, this work addresses gaps in harnessing its leaf chemistry for green technologies [19-20]. The leaves of *S. mahagoni* thus constitute a promising resource for the eco-friendly synthesis of nanomaterials and pharmaceuticals [21]. The physicochemical properties of the synthesized AuNPs and polyvinylpyrrolidone-functionalized AuNPs (PVP-AuNPs) were

characterized using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), high-resolution transmission electron microscopy (HR-TEM), and UV-Vis spectroscopy [22]. The resulting PVP-AuNPs underwent comprehensive characterization using these analytical techniques to assess their optical, morphological, and structural properties [23].

Swietenia mahagoni possesses a history of use in traditional medicine for treating various ailments, including rheumatism, menstrual pain, constipation, and blood sugar regulation [24]. Bioactive compounds isolated from *S. mahagoni*, such as swietemahonin, swietemahonolide, and swietemahonin, have been linked to antidiabetic effects. These compounds exhibit inhibitory activity against α -glucosidase and α -amylase enzymes, suggesting a potential mechanism for blood glucose modulation [25-26]. Furthermore, Mexicanolide-type limonoids and other beneficial compounds present in *S. mahagoni* fruit demonstrate significant anti-inflammatory, anti-proliferative, and antioxidant properties, underscoring their potential therapeutic value for inflammatory and metabolic disorders [27-28].

[1]Material And Method:

1.1Accumulation and Preparation of Plant raw Material

Using *Swietenia mahagoni* leaf, which is collected from agricultural and nursery sources in Mahesana, Gujarat, as a dual reducing and stabilising agent, this study describes a sustainable approach for the manufacture of gold nanoparticles (AuNPs). In order to reduce the environmental impact, the methodology used analytical-grade reagents without additional purification, adhering to the principles of green chemistry. Ultrapure Milli-Q water made sure that contaminants were removed during solution preparation, and polyvinylpyrrolidone (PVP, SD Fine Chemicals) and chloroauric acid ($\text{HAuCl}_4 \cdot x\text{H}_2\text{O}$, Sigma-Aldrich, USA) were utilised as the precursor and functionalising agent, respectively.

1.2Plant Extract Preparation

The plant material utilized in this investigation is *Swietenia mahagoni* which was collected from a farm. The fresh bark of the plant was carefully removed, subjected to multiple washes with Milli-Q water, and then dried in the shade. Subsequently, the dried bark was finely ground into a mixture. In the preparation process, 500 ml of Milli-Q water was combined with 50 grams of the plant pieces. The resulting mixture was brought to a boil at 80 degrees Celsius and maintained at this temperature for two hours.

1.3Green synthesis of gold nanoparticles:

In the process of synthesizing nanoparticles from the plant extract 60 ml of the extract was combined with 140 ml of $\text{HAuCl}_4 \cdot x\text{H}_2\text{O}$ (Gold) solution. Following the extraction process, the solution was used as a stock solution of plant extract for the production of gold nanoparticles (AuNPs). The mixture was then heated to

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80 degrees Celsius while being constantly stirred using a magnetic stirrer with a hot plate for a duration of 2 hours. The occurrence of a noticeable color change served as a confirmation of the synthesis of gold nanoparticles. The solution underwent filtration through Whatman filter paper, and the resulting filtrate was stored at a temperature range of 30 to 40 degrees Celsius, serving as the plant extract for subsequent AuNPs synthesis.



Fig.1 *Swietenia mahagoni*



leaf Extract



AuNPs



PVP-AuNPs

1.5 Characterization:

The biosynthesized gold nanoparticles (AuNPs) were characterized using a suite of complementary analytical techniques. Optical properties were monitored via UV-Visible spectroscopy (UV-Vis), which confirmed the formation of AuNPs through the observation of the characteristic surface plasmon resonance (SPR) band. UV-Vis measurements were conducted at room temperature over the course of the reaction, scanning the range of 200–800 nm with a resolution of 1 nm. Chemical functional groups associated with the synthesis were identified using Fourier Transform Infrared Spectroscopy (FTIR) in the range of 4000-400 cm^{-1} . High-resolution transmission electron microscopy (HR-TEM) was employed to analyze the size, distribution, and detailed structural morphology of the nanoparticles. Furthermore, the crystalline structure and phase purity of the AuNPs were investigated by X-ray diffraction (XRD) using a Rigaku D/MAX

1.4 Green Synthesis of Gold Nanoparticles Using PVP Compound:

In the initial step, 0.5 grams of PVP were dissolved in 250 ml of Milli-Q water and stirred for a duration of one hour. The AuNPs solution (150 mL) was progressively mixed with the aqueous PVP. the change in colour from a light brown colour to a dark brown. Subsequently, this PVP solution was gradually introduced into the homogenous solution of AuNPs, previously prepared from leaf extract.

diffractometer operating at 40 kV and equipped with a graphite monochromator. XRD analysis also allowed for the determination of the average crystallite size.

[2] RESULTS AND DISCUSSION:

AuNPs Biosynthesis was shown by the precursor solution changing brown and by the growth of dark brown precipitation on the reaction flask's inner surface. the reaction flask indicated that the biosynthesis of AuNPs was effective following the addition of switenia mahagoni leaf extract. The colour of a Nanoparticles is confirmed by the surface plasmon resonance (SPR).

2.1 UV-visible spectroscopy:

The experimental results in this work show that adding fresh leaf extract from Swenia mahagoni successfully synthesises b-AuNPs (b-AuNPs).

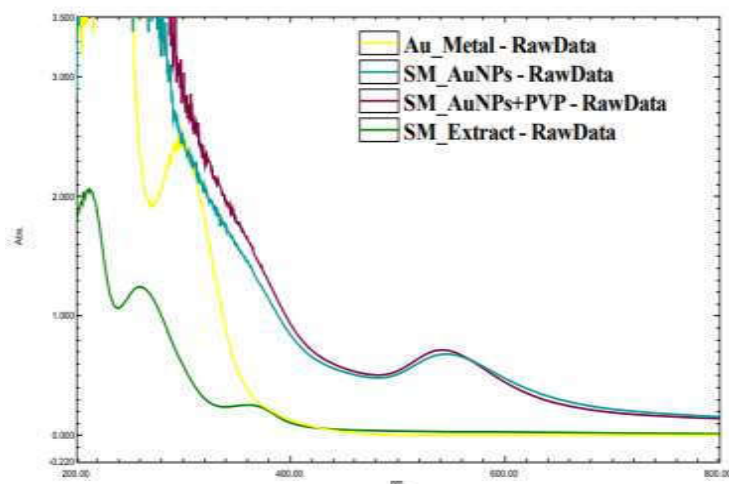


Fig. [2] UV-visible spectrum Analysis

The formation of bio-synthesized gold nanoparticles (b-AuNPs and PVP-b-AuNPs) using *S. mahagoni* leaf extract was confirmed by UV-visible spectroscopy. The reduction of Au^{3+} to Au^0 was initially indicated by a visual color change from pale brown to reddish-brown, a characteristic sign of surface plasmon resonance (SPR) in metallic nanoparticles. The UV-visible spectrum of the b-AuNPs exhibited a prominent absorption peak at 545 nm (Fig. 2), which is typical of the SPR band for spherical gold nanoparticles. This confirms the successful synthesis of b-AuNPs, with the peak position suggesting a specific size distribution consistent with SPR activity. These findings are in agreement with previous reports on the green synthesis of gold nanoparticles.[29-30]

The b-AuPvpNPs' identified surface plasmon resonance (SPR) peak at 542nm is in line with research on gold nanoparticles made with plant extracts. Successful polymer functionalisation for the PVP-b-AuNPs is confirmed by the observation of a new absorption band; this effect has also been reported for polymer-capped nanoparticles. Additionally, by creating a steric barrier that prevents agglomeration, the PVP coating greatly improved the colloidal stability of the nanoparticles. Applications needing monodisperse

suspensions and long-term stability depend on this property. [31-32]

2.2FTIR studies:

To explain the functional groups connected to biosynthesised gold nanoparticles (AuNPs) and AuNPs contained in polyvinylpyrrolidone (PVP), Fourier-transform infrared (FTIR) spectroscopy was utilised. The FTIR absorption bands at 3284, 2129, 3219, 655, and 472 cm^{-1} were clearly visible in the biosynthesised AuNPs. PVP-encapsulated AuNPs, on the other hand, showed clear peaks at 3639, 2736, 1965, and 1267 cm^{-1} . Additionally, a common spectral peak at 1417 cm^{-1} was shared by AuNPs and PVP-AuNPs, with is linked to C-H bonding in aliphatic or aromatic structures. PVP-AuNPs' broad absorption bands at 3639 cm^{-1} and biosynthesised AuNPs' at 3300 cm^{-1} were due to O-H stretching vibrations, which are a marker of phenolic hydroxyl groups that come from the reducing agent. C=C stretching vibrations were also consistent with peaks at 1647 cm^{-1} (biosynthesised AuNPs) and 1635 cm^{-1} (PVP-AuNPs), indicating the presence of aromatic groups or conjugated alkenes. [33-34]

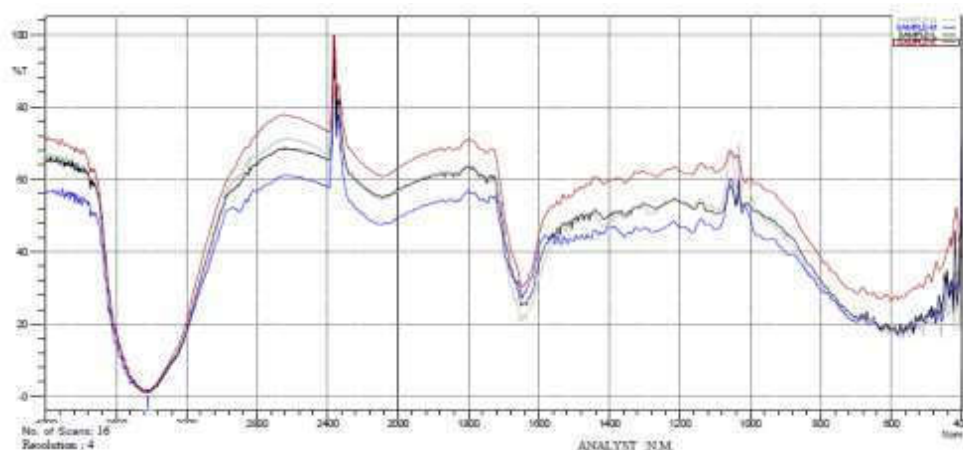


Fig.3 FTIR spectrum[A]P.E(Black)[B]AuNPs(Blue)[C]PVP-AuNPs(Silver)[D]Au Solution(Red)

Both types of nanoparticles were synthesised using an aqueous leaf extract of *Swietenia mahagoni* as a stabilising and reducing agent. The discovered wavelengths are consistent with previous research on plant-mediated AuNP production, which shows that terpenoids and polyphenolic chemicals in plant extracts help reduce gold ions and stabilise the resulting nanoparticles. As shown by the shift in O-H and C-H vibrational frequencies, which was probably caused by interactions between the polymer and phytochemical capping agents, the PVP encapsulation further altered the surface chemistry. These results support both the modification of surface characteristics through polymer functionalisation and the role of biomolecules in nanoparticle growth. [35-37]

2.3X- Ray Diffraction:

X-ray diffraction (XRD) was used to examine the structural characteristics of biosynthesised gold nanoparticles (AuNPs) and their polymeric equivalents. The face-centered cubic (FCC) crystalline structure of metallic gold (JCPDS No. 04-0784) is confirmed by the diffraction patterns, as illustrated in Fig. 2. At 2θ values of 38.63° (111), 44.88° (200), 65.01° (220), and 78.06° (311), characteristic peaks were seen, which were in agreement with the conventional lattice parameters of gold. The phase purity of the produced AuNPs is confirmed by the lack of impurity peaks.[38]

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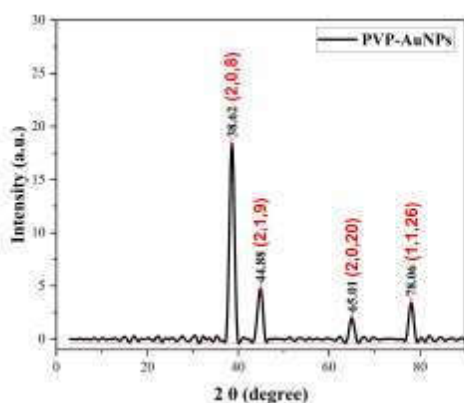


Fig 4XRD Pattern of PVP AuNPs

The small broadening of peaks, which may be the result of reduced crystallite size or strain effects brought on by the capping agent, shows the interaction between the PVP polymer and the nanoparticle surface.[39] The consistency of the diffraction profile shows that this stabilisation process, which is made possible by PVP, additionally limits collection but also changes the growth kinetics. The equation devised by is

used to estimate crystallite sizes, and the XRD evaluations confirm the creation of well-defined, FCC-structured AuNPs stabilised by PVP. The observed pattern is consistent with PVP-capped AuNPs reported in the literature, showing the synthesis protocol's effectiveness in creating monodisperse nanoparticles with defined structural characteristics.[40-41]

2.4 HR-TEM Analysis:

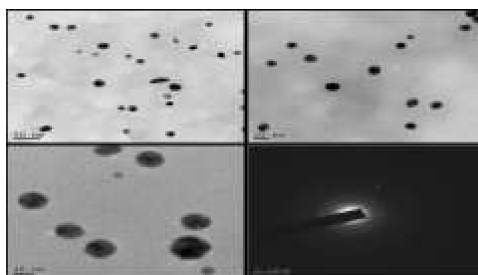


Fig.5 HR-TEM image of pvp AuNps observed at 50 nm [A] 20nm [B] 10nm[C] selected area electron diffraction (SAED) pattern[D]

Using high-resolution transmission electron microscopy (HRTEM), the produced polyvinylpyrrolidone (PVP)-encapsulated gold nanoparticles (AuNPs) exhibited a spherical shape with uniform collection and similar dispersion. *Swietenia mahagoni* leaf extracts included bioactive compounds that acted as both stabilising and reducing agents,

enabling the reduction of Au^+ ions to zero-valent gold nanoparticles (Au). Due to their abundance of surface-bound hydroxyl groups, these biomolecules prevented aggregation and allowed for the production of evenly distributed AuNPs. [42-43]

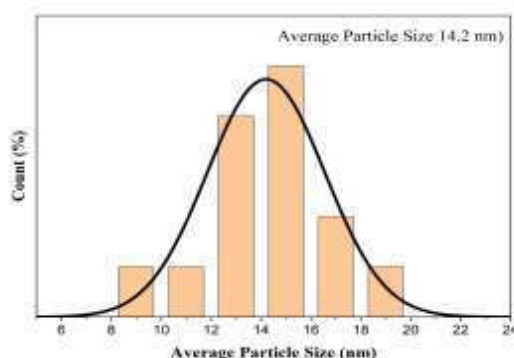


Fig.6 TEM analysis and SAED pattern pf PVP functionalized b-AuNPs

Transmission electron microscopy (TEM) was used to study the particle size distribution and characterise the synthesised material. The molecular characteristics and particle substances found in the leaf parts of *Swietenia mahagoni* were studied using TEM. An average particle size of 14.2 nm was identified by the analysis.[44]

Conclusion:

This study establishes a robust, green synthesis methodology for generating stable, monodisperse, spherical polyvinylpyrrolidone-capped gold nanoparticles (PVP-AuNPs) utilizing an aqueous extract of *Swietenia mahagoni*. The described protocol is notably facile, cost-effective, and environmentally benign. Critically, the extract-to-precursor ratio was identified as a key parameter governing nanoparticle size and monodispersity. This approach aligns with the principles of green chemistry, offering a sustainable pathway for nanomaterial production. While challenges in reproducibility at scale remain, this work provides a foundation for optimizing such eco-friendly methods for potential industrial and biomedical applications.

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