E-ISSN:2583-553X

Research Article

Green Synthesis

Applied Science and Biotechnology Journal for Advanced Research

2025 Volume 4 Number 5 September

Publisher

Vandana Publications

www.vandanapublications.com

Green Synthesis of Gold Nanoparticles using Extracts of C. guianensis: A Comparative Analysis of Reduction Efficiency and Antimicrobial Properties

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DOI:10.5281/zenodo.17292348

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A growing body of research highlights the potential of plant-mediated synthesis for producing gold nanoparticles (AuNPs) in an environmentally friendly manner. However, a knowledge gap exists regarding the comparative effectiveness of different plant parts in facilitating this process. This study addresses this gap by investigating the AuNP synthesis potential of C. guianensis leaf, fruit, and flower extracts. Our results show that these extracts can be successfully utilized for the rapid, one-pot synthesis of AuNPs with controlled size and morphology. A comprehensive characterization of the synthesized AuNPs was performed using a range of analytical techniques, including UV-vis spectroscopy, FESEM, DLS, XRD, and FTIR analysis. Furthermore, the antimicrobial activity of the synthesized AuNPs was evaluated, revealing a minimum inhibition concentration (MIC) of 0.048 mM against Gram-negative bacteria (E. coli).

Keywords: green synthesis, bacteria, biosensing

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Deepika Hasija, Department of Chemistry, Ramsheth Thakur College of Commerce and Science, Kharghar, Maharashtra, India. Email: deepikahasija@rtccs.edu.in	Hasija D, Lohakare N, Nagarekar R, Zirpe M, Green Synthesis of Gold Nanoparticles using Extracts of C. guianensis: A Comparative Analysis of Reduction Efficiency and Antimicrobial Properties. Appl Sci Biotechnol J Adv Res. 2025;4(5):22-28. Available From https://abjar.vandanapublications.com/index.php/ojs/article/view/109	

Manuscript Received	Review Round 1	Review Round 2	Review Round 3	Accepted
2025-08-07	2025-08-26			2025-09-16
Conflict of Interest	**Funding**	**Ethical Approval**	**Plagiarism X-checker**	**Note**
None	Nil	Yes	4.74	

1. Introduction

Metal nanoparticles have gained immense scientific and technological importance owing to their high surface-area-to-volume ratio and distinct physicochemical properties [1]. Among them, gold nanoparticles (AuNPs) stand out due to their remarkable stability, biocompatibility, and tunable optical features [2, 3], which have facilitated their use in applications ranging from biosensing and catalysis to drug delivery, cancer therapy, and antimicrobial treatments [4-6]. In particular, their shape- and size-dependent optical responses make AuNPs ideal candidates for diagnostic and therapeutic platforms in nanomedicine [7].

Despite the potential of AuNPs in biomedical applications, conventional synthesis methods often involve hazardous chemicals, energy-intensive processes, and environmental concerns. This has prompted a shift toward greener, more sustainable approaches, with biosynthesis, especially plant-mediated synthesis as an eco-friendly and scalable alternative [8-10]. Plants are particularly suitable for this purpose, as their extracts are rich in secondary metabolites such as flavonoids, phenolics, and alkaloids that function as natural reducing and stabilizing agents during nanoparticle formation.

Couroupita guianensis commonly known as the cannonball tree, is a medicinally significant species from the Lecythidaceae family. Traditionally used to treat a wide range of ailments—from bacterial infections and inflammation to skin disorders and malaria—its various parts contain a diverse array of bioactive compounds. This phytochemical richness makes it a promising candidate for green nanoparticle synthesis [11].

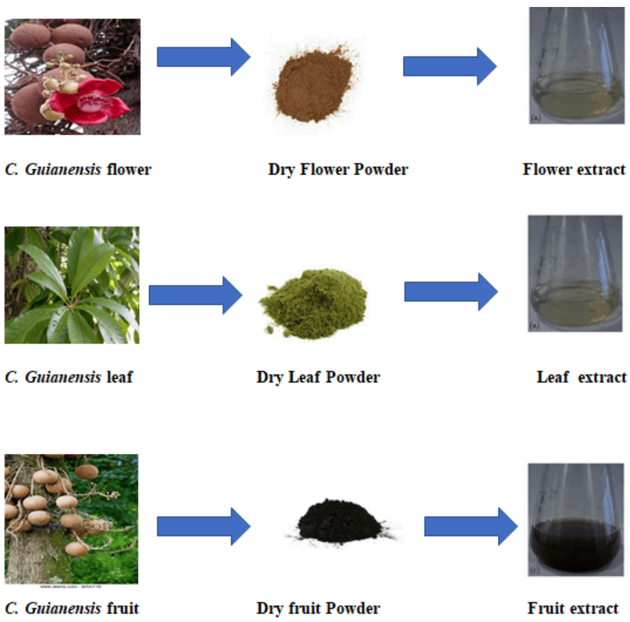
While prior research has demonstrated the feasibility of using individual plant parts in nanoparticle formation, comparative studies evaluating the synthesis efficiency and biological activity of AuNPs derived from different organs of a single plant remain limited [12]. The present study addresses this gap by investigating the green synthesis of gold nanoparticles using aqueous extracts from the leaves, fruits, and flowers of *C. guianensis*. The synthesized nanoparticles were characterized using UV–Vis spectroscopy, FESEM, DLS, XRD, and FTIR analyses to assess their morphological and structural attributes.

A key focus of this research is the evaluation of the antimicrobial potential of the synthesized AuNPs, particularly against *Escherichia coli*, a common Gram-negative pathogen. By examining differences in reduction efficiency and biological efficacy among the three extracts, this study aims to identify the most effective plant part for AuNP synthesis and explore the broader implications for eco-friendly antimicrobial nanomaterials.

2. Materials and Methods

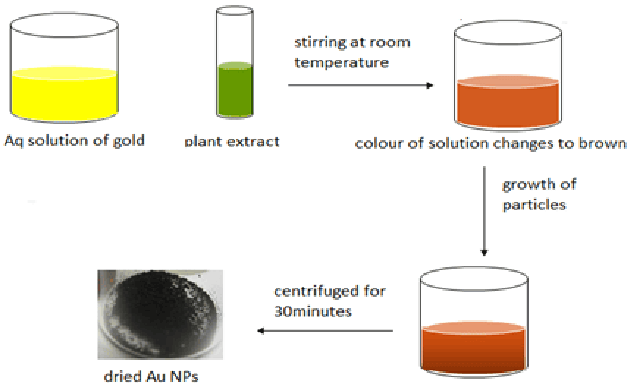
Plant material and preparation of the Extract

C. guianensis leaves, flowers, fruit, were collected from the Department of Chemistry, Mumbai University Campus, Maharashtra. The leaves, flower, fruit were washed thoroughly with double distilled water twice and dried in the sun for 3 days. These dried leaves, flower, fruit were then crushed into a fine powder. The fine powder was then made to undergo nitrogen treatment. Nitrogen treatment was done in order to prevent fungal growth and development on the plant material. 1g of the powder was added to distilled water and diluted to $100 cm^3$. This flask was placed in a sonicator so that plant particles dissolve effectively in water. The solution was then filtered 3 times using Whatman filter Paper No 41. Filtrate obtained was used as plant extract in synthesis.

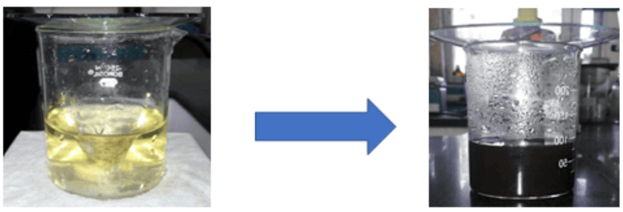


Synthesis of Gold Nanoparticles using Plant Extract

2ml of *C. guianensis* plant extract added to 50 ml of 1 mM HAuCl4. . Different reaction concentrations of *C. guianensis* extract and $HAuCl_4$ solution were subjected, respectively. The reduction of gold ions to gold nanoparticles was completed within 5 min. The pale yellow color solution turns to ruby red color indicating the formation of gold nanoparticles. The reduction of metal ions was continuously monitored by visual inspection as well as by measuring with UV–visible spectrometer in the wavelength range 540–570 nm.



Schematic representation of synthesis of AuNP



Before reduction After reduction

3. Characterisation

The AuNPs was characterized by UV-visible (vis) spectrophotometer, particle size analyzer (DLS), scanning electron microscopy (SEM), and Fourier transform infrared spectrometer (FTIR) analysis was carried out to determine the nature of the capping agents in each of these leaf, fruit, flower extracts. AuNPs obtained showed significantly higher antimicrobial activities against Escherichia coli (E. coli)

1. UV-vis Spectra Analysis

UV-visible (vis) spectra was done by using, UV-Visible spectrophotometer UV-2450(SHIMADZU). Which having resolution of 1nm.

The UV-Visible absorption spectra of gold nanoparticles synthesized using flower, fruit, and leaf extracts of Couroupita guianensis showed characteristic Surface Plasmon Resonance (SPR) peaks in the range of 540–550 nm, confirming the successful formation of AuNPs.[15, 16]. Absorbance readings were recorded at 15-minute intervals, which demonstrated a progressive increase in peak intensity over time, indicating the ongoing synthesis of nanoparticles. Additionally, increasing the extract volume from 2 mL to 8 mL resulted in higher absorbance values, reflecting greater nanoparticle yield. Among the different plant parts, the fruit extract exhibited the highest absorbance intensity, followed by the flower and leaf extracts, suggesting that the fruit contains a higher concentration of phytochemicals responsible for efficient reduction and stabilization of gold ions. These findings highlight the significant influence of both extract type and reaction time on the efficiency and kinetics of biosynthesized AuNP formation.

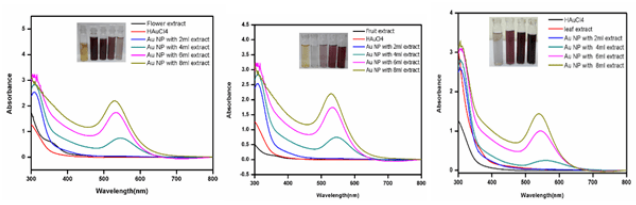


Figure 1 Figure 2 Figure 3

Figure 1, 2 and 3 corresponds to synthesis of gold nanoparticles with aq. extracts of flower, fruit and leaf of *C.* respectively at different volumes.

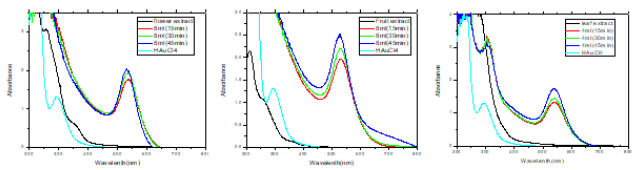


Figure 4 Figure 5 Figure 6

Figure 4, 5 and 6 corresponds to synthesis of gold nanoparticles using aq. extracts of flower, fruit and leaf at various time interval.

The synthesis of nanoparticle was highest with fruit followed by flower and leaf extracts.

4. FTIR Spectrum

The FTIR spectra of gold nanoparticles synthesized using *Couroupita guianensis* leaf, flower, and fruit extracts revealed key functional groups involved in the reduction and stabilization of AuNPs.

Broad absorption bands observed around 3300–3400 cm^{-1} correspond to O–H stretching vibrations of hydroxyl groups, indicating the presence of phenolic compounds and alcohols. Peaks around 1600–1650 cm^{-1}, attributed to C=C or C=O stretching, suggest the involvement of carbonyl and aromatic compounds in nanoparticle formation. Additional peaks near 1000–1100 cm^{-1} point to C–O stretching from esters or ethers [14, 15]. The FTIR spectrum of the synthesized AuNPs showed shifts and intensity changes in these regions, confirming the interaction between gold ions and the phytochemicals present in the extracts. These results collectively confirm that bioactive compounds in the plant extracts serve as both reducing and capping agents in the green synthesis of stable gold nanoparticles.

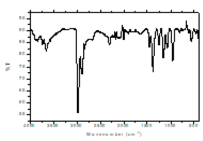


Figure (1) AuNP

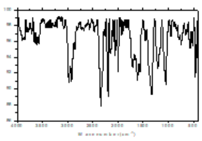


Figure (2) Fruit extract

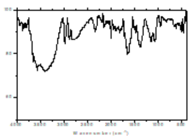
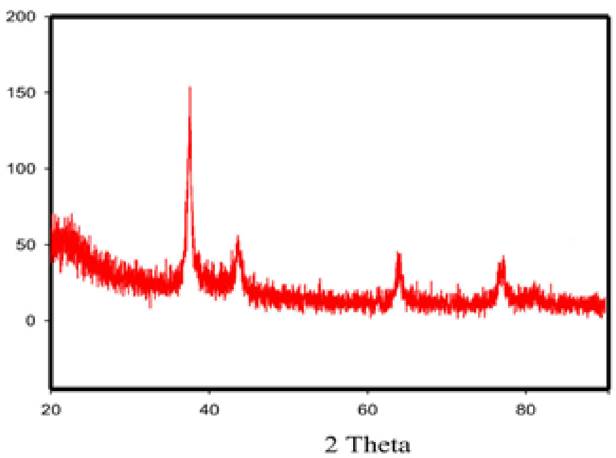


Figure (3) Flower extract



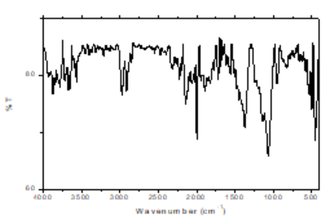


Figure (4) Leaf extract

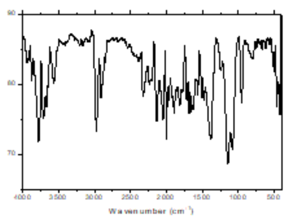


Figure (5) Precursor solution

5. X-Ray Diffractogram

It is important to know the exact nature of the gold nanoparticles formed, and this can be deduced from the XRD Spectrum of the Sample.

The well-resolved and intense XRD pattern clearly showed that the Au NPs formed by the reduction of Au^{3+} ions using C. guianensis plant extract.

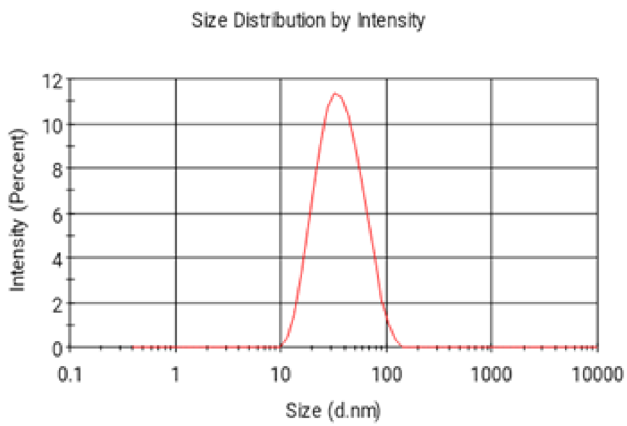
XRD of Gold Nanoparticles

In the case of gold nanoparticles in the whole spectrum of 2θ values ranging from 35° to 80°, four new reflection signals appear at 38.73°, 45.03°, 65.41°, and 78.26°in the XRD pattern of the Au, corresponding to the [111], [200], [220] and [311] planes of the Au, respectively as can be seen in below Figure , indicating that crystal structure of the gold nanoparticles was face centered cubic(JCPDS 4-0783)in this case [16].

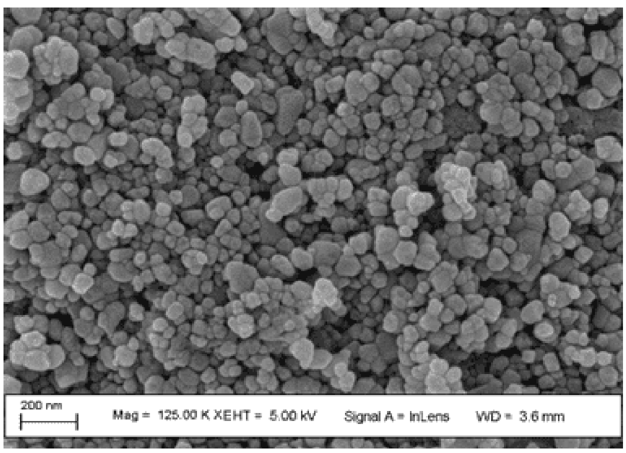
6. Particle Size Analysis

SEM analysis And DLS Analysis

Scanning Electron Microscopy (SEM) analysis of the *Couroupita guianensis* extract-mediated gold nanoparticles (AuNPs) revealed a predominantly distorted spherical morphology with noticeable agglomeration. The average particle size observed through SEM was in the range of 40–60 nm.



DLS spectrum of Au nanoparticle



FESEM of Au nanoparticle

Analysis using Dynamic Light Scattering (DLS) provided a detailed particle size distribution profile, reflecting the hydrodynamic diameter of the nanoparticles, including the surrounding capping layer of biomolecules. The DLS results indicated an average particle size in the range of 50–80 nm. The presence of slightly larger particles in the DLS profile can be attributed to the tendency of AuNPs to agglomerate in solution, which affects the overall hydrodynamic measurement

7. Application

Antibacterial Assay

The antibacterial activity of the biosynthesized gold nanoparticles (AuNPs) was assessed against the human pathogenic Gram-negative bacterium *Escherichia coli*. The bacterial cultures were grown using Luria Bertani (LB) medium, which was sterilized at 120 °C under pressure for 15 minutes. The pH of the medium was adjusted and maintained at 7.5 at 25 °C.

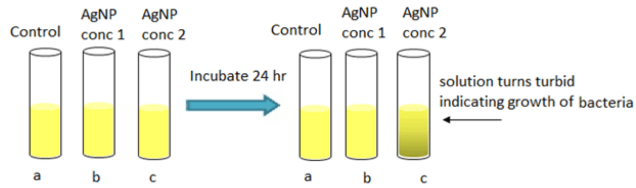
Preparation of LB Medium and Nanoparticle Dilutions

A 0.25 mM LB solution was prepared, and a series of AuNP concentrations ranging from 50 mM to 0.048 mM was formulated. Each test tube contained 2 ml of the LB medium and the respective AuNP solution. Fresh overnight bacterial cultures were used, and a double dilution method was employed. The bacterial inoculum was added to each test tube, while the control (blank) consisted of 2 ml of LB medium with bacterial culture but without AuNPs.

Following incubation at 37 °C for 24 hours, bacterial growth was monitored. The extent of growth inhibition was assessed by measuring the optical density using a Thermo Scientific spectrophotometer. The formation of inhibition zones and reduction in optical density indicated effective antibacterial action of the gold nanoparticles.

8. Bacterial Activity of Gold Nanoparticles

The antimicrobial activity of the biosynthesized gold nanoparticles was evaluated against *Escherichia coli*, a Gram-negative bacterium, using a zone of inhibition assay. Varying concentrations of AuNPs demonstrated concentration antimicrobial effects, with clear inhibition zones observed. Notably, significant bacterial growth suppression was observed even at concentrations below 0.048 mM. The minimum inhibitory concentration (MIC), defined as the lowest concentration at which visible bacterial growth is completely inhibited, was determined to be 0.048 mM for the AuNPs. These findings highlight the potent antibacterial efficacy of *Couroupita guianensis*-mediated gold nanoparticles, particularly at relatively low concentrations, indicating their strong potential for use in antimicrobial applications[17].



Concentration in mM	0.0	0.0488	0.097	0.195	0.391	0.781
Bacterial growth	0.3783	0.008	0.0	0.0	0.0	0.0
Percentage	0.0%	97.88%	100%	100%	100%	100%

Positive	0.378
Medium	0.00
Control	0.583

9. Result and Discussion

The successful synthesis of gold nanoparticles (AuNPs) using *Couroupita guianensis* leaf, fruit, and flower extracts was confirmed by a visible color change and UV–Visible spectroscopy, which showed characteristic Surface Plasmon Resonance (SPR) absorption between 500–800 nm. Among all extracts and concentrations tested (2–8 mL), fruit extract at 8 mL exhibited the highest absorbance, indicating efficient nanoparticle formation, especially over a 24-hour period. FTIR analysis revealed the presence of bioactive compounds such as flavonoids, phenols, saponins, and glycosides, which played a dual role in reducing Au^{3+} ions and stabilizing the nanoparticles. Prominent peaks at 763 cm^{-1} and 439 cm^{-1} corresponded to C–H bending and Au–O bonding, confirming the involvement of plant metabolites in nanoparticle synthesis. Further characterization through XRD, SEM, and DLS showed that the synthesized AuNPs were predominantly spherical and crystalline, with an average particle size of 50–80 nm. Antibacterial testing against *E. coli* demonstrated that the AuNPs, particularly those synthesized using fruit extract, exhibited strong antimicrobial activity, likely due to both their size and bioactive surface chemistry.

10. Conclusion

In summary, the present study successfully demonstrates a green, sustainable, and efficient method for the synthesis of gold nanoparticles (AuNPs) using aqueous extracts of *Couroupita guianensis* plant parts—leaf, fruit, and flower. The synthesis was visually indicated by a color change due to Surface Plasmon Resonance (SPR) and confirmed by UV-Visible spectroscopy, with absorption peaks ranging from 500–800 nm. FTIR analysis revealed the involvement of bioactive phytochemicals such as flavonoids, phenolics, and saponins in the reduction and capping of AuNPs. Structural and morphological characterization through XRD, SEM, and DLS confirmed the formation of crystalline, spherical nanoparticles with an average size of 50–80 nm. Among the tested extracts, the fruit extract showed superior reducing ability and produced AuNPs with the most pronounced antibacterial activity against *E. coli*, indicating their potential for biomedical applications. Overall, this work highlights *C. guianensis* as a promising biogenic source for the eco-friendly synthesis of functional gold nanoparticles with notable antimicrobial properties.

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