

Comparative FTIR Characterization and Functional Group Profiling of Green-Synthesized Silver Nanoparticles from *Saraca asoca* and *Crateva Adansonii*

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Abstract: Silver nanoparticles were synthesized through a plant-mediated approach using aqueous leaf extracts of *Saraca asoca* and *Crateva adansonii* as reducing and stabilizing sources. Nanoparticle formation was initially indicated by the characteristic colour change and evaluated using FTIR. FTIR analysis identified hydroxyl, amine, carbonyl, aromatic, and C–O-containing functional groups associated with plant biomolecules that may participate in silver-ion reduction and nanoparticle stabilization. Both plant systems showed broadly comparable functional-group involvement, with differences in their FTIR absorption profiles. The findings support the feasibility of these medicinal plant extracts for green synthesis of silver nanoparticles. Further characterization of particle size, morphology, crystallinity, stability, and biological activity is required to establish their physicochemical properties and potential applications.

Keywords: *Saraca asoca*, *Crateva adansonii*, silver nanoparticles, green synthesis, FTIR

1. Introduction

Nanotechnology is among the fastest-growing areas of modern medical science. It deals with the study of materials at the nanoscale, generally taken as 1 to 100 nm, and has opened new opportunities in fields such as dentistry, pharmaceuticals, and bioengineering [1]. A central aim of nanoscience is to produce safe, environmentally friendly nanoparticles that can be widely adopted in nanotechnological applications [2]. Metals at the nanoscale have a larger surface area than their bulk counterparts and, because of size-dependent, surface, interfacial, and quantum effects, show physical and chemical properties that are absent in bulk metals. Metal nanoparticles are now used widely in biology, medicine, and engineering; stabilized zero-valent iron nanoparticles, for example, have been applied to soil and groundwater remediation [3].

Conventional methods for producing nanoparticles (NPs) are costly, toxic, and harmful to the environment. To overcome these drawbacks, researchers have turned to green routes that use naturally occurring sources and their products. The present work investigates the synthesis of stable silver nanoparticles (AgNPs) using leaf extracts of two medicinal plants, *Saraca asoca* and *Crateva adansonii*, and their characterization by FTIR spectroscopy.

2. Literature Survey

2.1 Green synthesis of nanoparticles

Green synthesis can be grouped into three categories: (a) microorganisms, including fungi and yeasts (eukaryotes) as well as bacteria and actinomycetes (prokaryotes); (b) plants and plant extracts; and (c) templates such as membranes,

viruses, DNA, and diatoms. Synthesis mediated by bacteria, fungi, plants, and plant extracts is described in detail by Rafique *et al.* [1]. Of these, the plant-mediated approach is the most common and the most widely studied. It can draw on leaves, roots, stems, fruits, flowers, or whole-plant extracts. Plant metabolites such as flavonoids, alkaloids, phenolics, terpenoids, and sugars act in two ways: as reducing agents, which convert metal ions into metal NPs, and as capping or stabilizing agents, which prevent aggregation. Plant extracts are particularly rich in flavonoids, phenols, and terpenoids, whose reducing and capping properties are essential for forming and stabilizing nanoparticles.

Green synthesis produces NPs by environmentally friendly methods that avoid use of harmful chemicals, and its potential to lower the toxicity of NPs makes it especially attractive. Vitamins, amino acids, and plant extracts have consequently become increasingly popular for this purpose [4]. Medicinal plants are both useful and economically important, since they contain active constituents used to treat many human diseases [5]. Among the compounds produced by plants, phytochemicals, which are products of primary and secondary metabolism such as antioxidants, flavonoids, flavones, isoflavones, catechins, anthocyanidins, isothiocyanates, carotenoids, and polyphenols, are the most potent materials for biological activity and are recognized as important natural resources for the synthesis of metallic nanoparticles [6].

2.2 *Saraca asoca*

Saraca asoca (Roxb.), commonly known as the Ashoka tree, is a folk medicinal plant found in India, Bangladesh, and Sri Lanka and belongs to the family Caesalpiniaceae. Various parts of the plant contain many primary and secondary

metabolites, including flavonoids, terpenoids, saponins, phenols, tannins, lignin, cardiac glycosides, and proteins [7]. In Ayurveda, it has traditionally been used to treat gynaecological disorders and skin diseases and as an anti-inflammatory agent [8]. More recent studies have begun to examine its potential in nanotechnology, particularly for the synthesis of AgNPs [9].

2.3 *Crateva adansonii*

Crateva adansonii DC, of the family Capparidaceae, is known for medicinal properties that include anti-inflammatory, antimicrobial, and antidiabetic effects, and different parts of the plant are widely used in folk medicine for many disease conditions [10]. Its leaf extracts are applied externally for inflammatory conditions accompanied by pain and are also used to treat ear infections, while powdered bark is used for rheumatism, itch, epilepsy, asthma, and gastrointestinal and uterine infections.

3. Problem Definition

Plant-mediated synthesis offers a greener alternative to conventional physical and chemical routes, yet studies on the green synthesis of AgNPs using *C. adansonii* remain limited, even though its rich phytochemical profile suggests that it could serve this purpose. Examining its leaf extract for AgNP synthesis may open the way to novel antimicrobial agents.

The objective of this work is therefore to synthesize AgNPs from aqueous leaf extracts of *S. asoca* and *C. adansonii*, without hazardous chemicals, and to identify by FTIR spectroscopy the functional groups likely responsible for reducing silver ions and capping the particles.

4. Methodology

4.1 Sample collection

Fresh, healthy leaves of *Saraca asoca* and *Crateva adansonii* were collected and transported to the laboratory (Figure 1a).

4.2 Preparation of leaf extract

The collected leaves were washed three times with distilled water to remove dust and other impurities and were then dried in the shade for 3 to 4 days (Figure 1b, c). The dried leaves were cut into small pieces, ground to a powder (Figure 1d, e), and about 20 g was weighed out. The 20 g of leaf powder was placed in a clean conical flask with 100 mL of distilled water, and the mixture was boiled for about 15 minutes (Figure 1f). After cooling, the extract was filtered through Whatman No. 1 filter paper and stored at 4 °C until use (Figure 2).



Figure 1: Sample collection and leaf extract preparation: (a) fresh leaves, (b, c) leaves after washing and shade drying, (d) grinding, (e) leaf powder, (f) boiling of the powder in distilled water

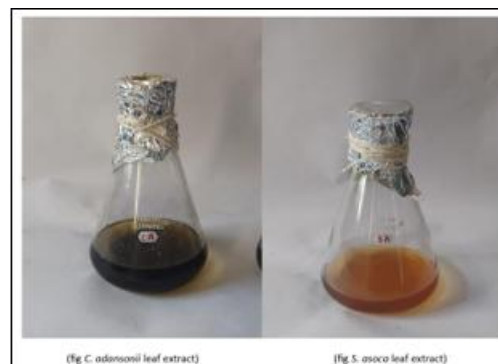


Figure 2: Leaf extracts of *C. adansonii* (left) and *S. asoca* (right)

4.3 Preparation of silver nitrate solution

The silver nitrate solution was prepared by dissolving 0.421 g of silver nitrate in 1000 mL of distilled water.

4.4 Synthesis of silver nanoparticles

Twenty millilitres of *S. asoca* or *C. adansonii* leaf extract was mixed with 180 mL of 1 mM silver nitrate and heated at 60 °C for 30 min on a hot plate with magnetic stirring (Figure 3). The mixture changed from light greenish yellow to dark brown, indicating the formation of silver nanoparticles. The solution was then left in the dark for one day.

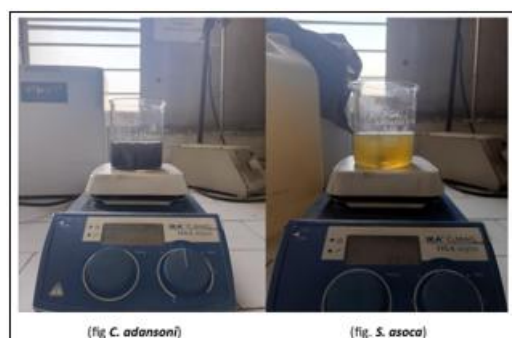


Figure 3: Reaction mixtures of *C. adansonii* (left) and *S. asoca* (right) on a magnetic stirrer hot plate

4.5 Centrifugation and recovery of AgNPs

The solution was centrifuged at 5000 rpm for *Saraca asoca* and 12,000 rpm for *Crateva adansonii*. A distinct pellet at the bottom of the centrifuge tubes was taken as evidence that

silver nanoparticles had formed (Figure 4). The pellet, consisting of the AgNPs, was carefully separated, and the supernatant, which contained residual plant extract and unreacted silver ions, was discarded. The pellet was then dried for further characterization and analysis. Different centrifugation speeds were used because the two nanoparticle preparations showed different sedimentation behaviour; *S. asoca*-mediated AgNPs formed a distinct pellet at 5000 rpm, whereas *C. adansonii*-mediated AgNPs required centrifugation at 12,000 rpm to obtain adequate pellet formation.

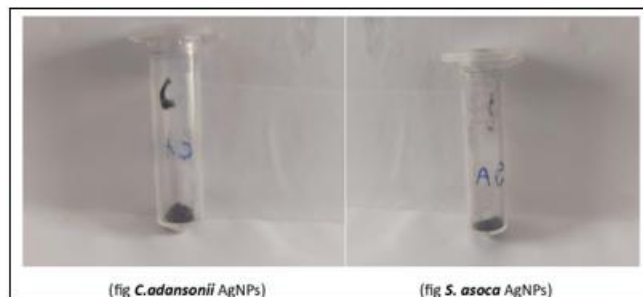


Figure 4: AgNP pellets of *C. adansonii* (left) and *S. asoca* (right) after centrifugation

4.6 Characterization

In the present work, nanoparticle formation and the functional groups associated with reduction and capping were identified by FTIR spectroscopy.

5. Results and Discussion

5.1 Visual observation and pellet formation

On heating with silver nitrate at 60 °C, the reaction mixture changed from light greenish yellow to dark brown, indicating the reduction of silver ions and the formation of AgNPs (Figure 3). After centrifugation, a distinct pellet was obtained for both *S. asoca* and *C. adansonii* (Figure 4), which was taken as evidence of nanoparticle formation.

5.2 Fourier transform infrared spectroscopy (FTIR)

FTIR spectroscopy was used to identify the functional groups that may be involved in the reduction and stabilization of the silver nanoparticles [11].

a) *Crateva adansonii*

The spectrum (Figure 5) showed prominent absorption bands at 3393, 2916, 2848, 1604, 1443, 1386, and 1026 cm^{-1} , together with bands in the lower region between 690 and 440 cm^{-1} . The broad band at 3393 cm^{-1} corresponds to O–H stretching of alcohols and phenolic compounds and points to polyphenolic constituents in the leaf extract. The bands at 2916 and 2848 cm^{-1} are attributed to C–H stretching of aliphatic groups, suggesting that organic biomolecules are involved. The strong band at 1604 cm^{-1} is assigned to C=O stretching of amide linkages (amide I), which indicates that proteins may have contributed to capping and stabilizing the nanoparticles. The band at 1443 cm^{-1} arises from C–H bending of alkanes, whereas the band at 1386 cm^{-1} is associated with C–N stretching of aromatic amines and O–H bending of

phenols. The band at 1026 cm^{-1} is attributed to C–O stretching, which may reflect polysaccharides or alcohols in the leaf extract. In the lower-frequency region, the bands at 690, 530, and 440 cm^{-1} may be associated with metal–oxygen (Ag–O) vibrations and are taken only as supporting evidence of nanoparticle formation, to be interpreted cautiously alongside the UV-Visible data. Taken together, these results suggest that phytochemicals such as phenolic compounds, proteins, and polysaccharides in the *C. adansonii* leaf extract may have contributed to the bioreduction of silver ions (Ag^+) to elemental silver (Ag^0) and in stabilizing the nanoparticles.

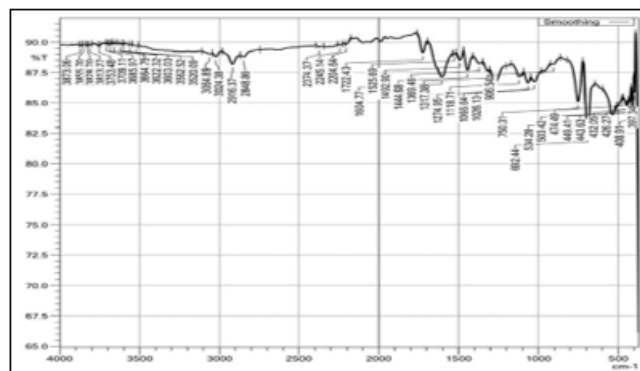


Figure 5: FTIR spectrum of *C. adansonii* leaf extract

b) *Saraca asoca*

The spectrum (Figure 6) showed major absorption peaks at 3664, 3161, 3047, 2486, 2376, 2272, 1988, 1597, 1510, 1343, 1313, 1119, and 1014 cm^{-1} and, in the lower region, at 767, 450, 422, and 397 cm^{-1} . The broad bands at 3664, 3161, and 3047 cm^{-1} correspond to O–H stretching of hydroxyl groups and N–H stretching of amines, suggesting that phenolic compounds and proteins take part in nanoparticle synthesis. The weak bands between 2486 and 2272 cm^{-1} may arise from atmospheric CO_2 and were regarded as negligible for characterizing the sample. A weak peak at 1988 cm^{-1} could be attributed to C=O stretching or to C=C overtone vibrations of conjugated carbonyl compounds. The strong bands at 1597 and 1510 cm^{-1} correspond to C=C stretching of aromatic rings or to amide II groups of proteins, pointing to protein-mediated reduction and capping of the nanoparticles. The peaks at 1343 and 1313 cm^{-1} are assigned to C–N stretching of amines or to CH_2 bending, which further supports the involvement of biomolecules. The peaks at 1119 and 1014 cm^{-1} result from C–O–C and C–O stretching, respectively, indicating ethers and polysaccharides. The sharp peak at 767 cm^{-1} is attributed to out-of-plane C–H bending of aromatic compounds. Finally, the low-wavenumber peaks at 450, 422, and 397 cm^{-1} may be associated with metal–oxygen (Ag–O) vibrations and are taken only as supporting evidence of nanoparticle formation, to be interpreted cautiously alongside the UV-Visible data. These findings suggest that phytochemicals such as phenols, proteins, and polysaccharides in the *S. asoca* leaf extract may have taken part in reducing the silver ions and stabilizing the resulting nanoparticles.

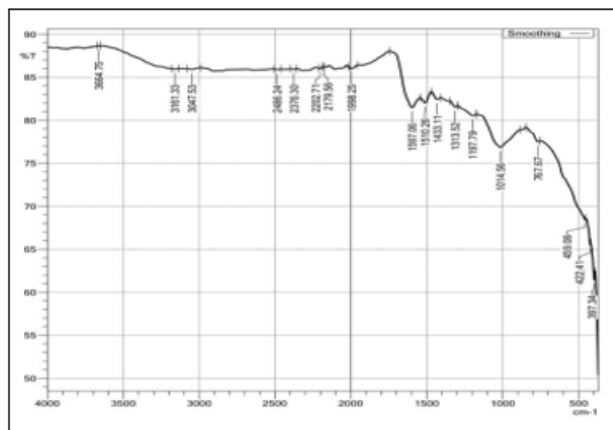


Figure 6: FTIR spectrum of *S. asoca* leaf extract

6. Conclusion

The study demonstrates a plant-mediated approach for producing silver nanoparticle preparations using aqueous leaf extracts of *Saraca asoca* and *Crateva adansonii*. FTIR analysis indicated the involvement of hydroxyl-, amine-, carbonyl-, aromatic-, and C–O-containing biomolecules, suggesting contributions from phenolic compounds, proteins, and polysaccharides to silver-ion reduction and nanoparticle stabilization. The two plant systems showed related but distinct FTIR profiles. These findings support the feasibility of using both extracts for green AgNP synthesis. Additional characterization by complementary techniques is required to establish particle size, morphology, crystallinity, elemental composition, stability, and biological activity.

7. Future Scope

The present work describes the synthesis of AgNP preparations from the two leaf extracts and identifies, by FTIR, the functional groups possibly involved in reduction and stabilization. Particle size, shape, and crystallinity have not yet been determined. Complementary techniques such as XRD (crystalline structure and phase purity), SEM (surface morphology), TEM (particle size and shape), and EDX (elemental composition) are needed to establish these properties. Detailed studies of stability, size distribution, and bioactivity are currently in progress. Given their distinctive physicochemical properties, the AgNPs may be useful in antimicrobial therapy, drug delivery, and diagnostics, and these applications remain to be tested.

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