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Research Article

Green synthesis, characterization of silver nanoparticles from *Aglaomorpha quercifolia* rhizome

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Abstract: The ability of silver nanoparticles (Ag-NPs) to effectively target particular tissues and harmful microbes has attracted a lot of attention to their green manufacture. The production and characterisation of Ag-NPs utilizing *Aglaomorpha quercifolia* rhizome extract are the main objectives of this work. When 0.1 mM of silver nitrate (AgNO₃) was used to create stable AgNPs, the solution's colour changed from yellow to brown, signifying the creation of nanoparticles. Spectrophotometric analysis, which tracked the optical density, verified this transition. The crystalline nature of the generated Ag-NPs was verified by X-Ray Diffraction (XRD). Using Fourier Transform Infrared Spectroscopy (FTIR) research, functional groups that functioned as stabilizing and capping agents were identified. This implied the existence of carboxylic acids and amide bonds, which aided in the reduction of silver ions. The size and shape of the Ag-NPs were examined using Scanning Electron Microscopy (SEM), and their constituent elements were examined using Energy Dispersive X-ray Spectroscopy (EDX). A noticeable signal at 3 keV confirmed that metallic silver was present in the nanoparticles.

Key Words: *Aglaomorpha quercifolia*, Silver nanoparticles (Ag-NPs), X-Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDX)

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Introduction

The creation of nanoparticles (NPs) with a range of sizes, shapes, and controlled dispersities for usage in a variety of ways is a component of nanotechnology. Due to its widespread application in many scientific and technological domains, it has the potential to have an impact on human society (Siddiquee *et al.*, 2020). Applications of metal nanoparticles include antimicrobial, dental therapy, wound healing, surgical function, catalyst, and biomedical devices (Tade *et al.*, 2020). It has been discovered that NP-based medications are more effective due to their distinct optical and electrical characteristics (Smith *et al.*, 2017). One well-known characteristic of NPs that boosts their efficacy is surface plasmon resonance

(SPR) (Jabir *et al.*, 2021). With their unique physicochemical characteristics, high surface-to-volume ratio, narrow plasmon resonance, and numerous uses in biological activities, microelectronics, and medical research, silver nanoparticles (Ag-NPs) are remarkable (Gul *et al.*, 2021; Nouri *et al.*, 2020). Because Ag-NPs are widely used in a number of pharmacologically and commercially relevant products, they have attracted a lot of attention among other metal NPs (Das *et al.*, 2021; Mohammed *et al.*, 2021). When it comes to synthesis, the conventional techniques—physical, thermal, hydrothermal, and chemical synthesis modes—are costly, highly dangerous, and require hazardous materials. Thus, for the effective formation of NPs, the focus is on a green synthesis technique that utilizes

biological resources (Gul *et al.*, 2020; Nasrollahzadeh *et al.*, 2018). Using renewable resources and eco-friendly substances as reducing/capping agents to create green nanoparticles is the mainstay of this sustainable process (Mahdiani *et al.*, 2018). Utilizing various biomolecules, including vitamins, yeasts, enzymes, algae, biodegradable polymers, microorganisms, and plant parts like leaves, stems, gum, fruit, bark, shells, roots, buds, and flowers, green synthesis techniques have been successfully applied to the synthesis of nanoparticles (NPs) (Mankodi *et al.*, 2013).

Due in large part to the careless use of synthetic antimicrobial medications, which are frequently employed to treat infectious diseases, the prevalence of various resistances in human pathogenic bacteria has increased recently. This has led researchers to look for novel antimicrobials from a variety of sources, including therapeutic plants (Wu *et al.*, 1999). The oak leaf fern is the common name for *Aglaomorpha quercifolia*. It is a large herb with woody, highly scaled rhizomes. Adult plants have two types of leaves: 1) permanent bract leaves that are sessile and cordate-oblong, with a pinkish lobed edge that clasps the rhizome to act as human collectors, and 2) regular, oblong, pinnate-like leaves that are approximately a foot long and have a firm, brownish, winged petiole. Bract leaves are persistent, brittle, black, hard structures with

a strong midrib and primary lateral veins that adhere to the rhizome. They can grow up to 9 inches long and 6 inches wide. Each segment of a normal lamina leaf is linear with a wide base, tapering apex, and whole edge, measuring two to three feet in length and one foot in width. Venation is a rhetorical device. All young plant leaves (those under two or three years old) are sessile, simple lanceolate, with reticulated veins and attenuated bases. Creating and characterizing silver nanoparticles from *Aglaomorpha quercifolia* is the study's goal.

Materials and Methods Collection of Plant Material

After being carefully cleaned, the rhizome of the plant *Aglaomorpha quercifolia* was acquired from G. Madugula in the Alluri Seetharamaraju District. The samples that were gathered were verified by Andhra University's Department of Botany. The plant was initially cleaned to remove any dirt and impurities in order to ensure the elimination of microbiological pollutants. A solution of mercuric chloride (HgCl₂) was then used to disinfect it. Following the disinfection process, the facility was cleaned again to remove any last traces of chemical residue. The plucked rhizome was then allowed to dry for six to seven days at room temperature under cover to avoid the plant material's quality being compromised by direct sunlight.

Plate-1

Research Material for synthesis of silver nanoparticles and biological activities



a) *Aglaomorpha quercifolia* (synonym *Drynaria quercifolia*) whole plant, b) Rhizome



c) *Aglaomorpha quercifolia* rhizome collected by tribal man,

d) Single Rhizome.

Preparation of extract

Before being rinsed with distilled water, the fresh *Aglaomorpha quercifolia* rhizome was properly cleansed multiple times with running tap water to remove any dust or dirt. The rhizome was washed and left to dry for 20 days at room temperature in a protected environment to make sure the moisture content was gone. When the dried rhizomes were totally dry, they were ground into a fine powder using a mortar and pestle. A 500 mL conical flask was filled with 450 mL of methanol and 50 g of the powdered rhizome for extraction. The mixture was then shaken using a mechanical shaker for 30 minutes to ensure that the solvent and plant material were well combined. The flask was then heated to 65°C on a hotplate with a magnetic stirrer for an hour in order to expedite the extraction process. The mixture was then allowed to cool to room temperature. After cooling, the extract was filtered using Whatman No. 1 filter paper to provide a clear solution. The filtrate was carefully collected and stored at 4°C for use in the upcoming experiments.

Synthesis of nanoparticles

Silver nitrate (AgNO_3) served as the precursor for the production of silver nanoparticles. A final concentration of 0.1 mM at room temperature was obtained by combining 25 mL of the plant extract with 75 mL of the silver nitrate solution. This was carried out following the creation of a silver nitrate 0.1 mM aqueous solution. After two minutes, the solution's colour clearly changed from colourless to dark yellow, indicating the presence of silver nanoparticles. Five minutes later, the colour deepened considerably further, turning dark brown. The reduction of silver ions was confirmed by looking at the UV-Vis spectra of the solution. To separate the generated nanoparticles, the mixture was centrifuged for 20 minutes at 10,000 rpm. The pellet was carefully taken from the tube's bottom after the final centrifugation, placed on a watch glass, and dried in a hot air oven at 60°C.

Characterization of synthesized nanoparticles

A UV-Visible spectrophotometer (UV-2450, Shimadzu) was used to initially characterize the synthesized Ag-NPs in the 320–560 nm range, using a control as the reference. The stability of the Ag-NPs was tested by keeping them at room temperature for three months, and the surface plasmon resonance peaks were found to be consistently around the 420 nm region. Ag-NPs were analyzed using FTIR (IR Prestige21, Shimadzu) with a resolution of 4 cm^{-1} and a spectrum scanning range of 450–4000 cm^{-1} . After being freeze dried on a lyophilizer, the biologically produced silver

nanoparticles were ground into a powder and subjected to X-ray diffraction (XRD) analysis. A JEOL-JSM-6610 scanning electron microscope (SEM) was used to perform the analysis. A very little amount of the sample was dropped onto a carbon-coated copper grid to create thin films. Any excess solution was then wiped off using blotting paper, and the SEM grid's film was left to dry for five minutes under a mercury lamp. Scanning electron microscopy (SEM) was used to analyze the Ag-NPs' morphology at various magnifications. Compositional analysis on the sample was carried out by the energy dispersive X-ray spectroscopy (EDS) attached with the SEM. The EDX analysis of silver nanoparticle sample was done. The EDX normally reveals elemental analysis of solution.

Results and Discussion Extracellular synthesis of Ag-NPs

The extracellular generation of silver nanoparticles (Ag-NPs) was examined in detail in this work. The rhizome extract of *Aglaomorpha quercifolia* was first filtered, and the filtrate was then combined with a solution of silver nitrate (AgNO_3). The combination underwent a discernible colour shift over a 24-hour incubation period in a dark setting, indicating the successful production of nanoparticles.

The synthesis of Ag-NPs was demonstrated by the cellfree filtrate (CFF) changing from a pale yellow to a dark brownish-yellow colour (Fig.1). The observed colour change is caused by the interaction of the nanoparticles with light, which is known as SPR. In addition to indicating the development of Ag-NPs, this visual observation also points to their consistent synthesis under the specified experimental circumstances.

The production of silver nanoparticles, which may be further described by their size, shape, and biological activity, is made easy and environmentally beneficial by this extracellular synthesis process that uses plant extracts. Additionally, when the temperature and incubation period increased, the light brown solution containing AgNO_3 and plant extracts turned dark brown. Ag-NP synthesis in solution is indicated by this colour shift (Mukunthan *et al.*, 2011). When the reaction mixture turned from light yellow to brown and finally to dark brown, Ag-NPs mediated by *W. somnifera* roots were phyto-fabricated. This color change is the first indication of Ag-NP synthesis due to the optical properties of Ag-NPs (Shazina Jabeen *et al.*, 2023).

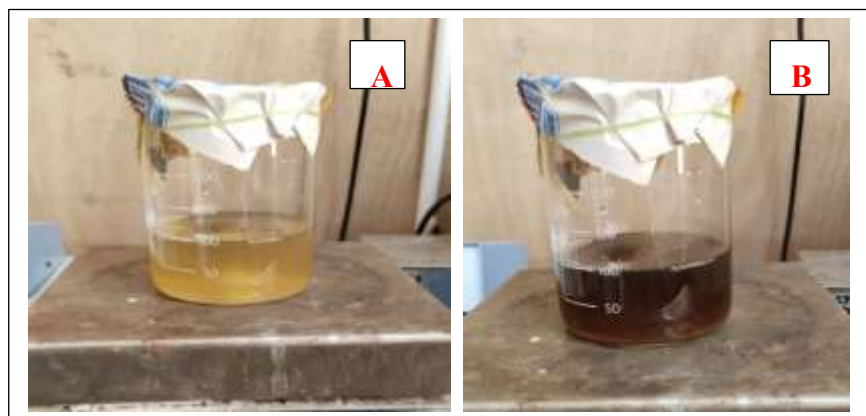


Fig. 1 Physical observation on (a) Control and (b) synthesis of Ag NPs

UV-Visible spectra of Ag NPs

UV-Vis absorption spectroscopy is an essential biophysical method for monitoring the stability and production of green nanoparticles by using the absorption spectrum. Figure 2 displays the Ag-NPs absorption spectra as determined by UV-Vis spectroscopy. In addition to the strongest absorption peak, which correlated with the plasmon resonance, this spectrum showed a broad peak at 436 nm. A substantial peak at a frequency that increases with wavelength indicates nanoparticle size, while a straight line at a wavelength that lowers indicates smaller particle size, per the findings of a previous study (Khan *et al.*, 2013). By using UV-visible spectroscopy, the creation of nanoparticles in aqueous solution was further verified. The wavelength scale was set between 300 and 600 nm, and the solution was scanned within that range.

The highest absorption, characteristic of silver nanoparticles, was recorded at 440 nm (Bahuguna *et al.*, 2016). One essential and useful method for thoroughly classifying produced nanoparticles is UV-vis spectroscopy. Additionally, it is employed to examine the production process and the stability of Ag-NP (Rao *et al.*, 2013). Ag-NPs interact strongly with particular

light wavelengths due to their special optical characteristics (Sulaiman *et al.*, 2014). Additionally, UV-Vis spectroscopy is said to be quick, straightforward, and easy to use. It is sensitive and selective for NPs and can measure a wide variety of them rapidly. Moreover, calibration is not necessary for the characterization of colloidal suspension particles (Baalousha *et al.*, 2011). Ag NPs are produced by a colored technique that has a vivid and noticeable hue.

A silver nitrate solution and *D. quercifolia* leaf methanol extracts were suggested by Rajagopal Kanagalatha and Geetha Chinnusamy (2022) (Proposito *et al.*, 2016) as a buffer. The final solutions were centrifuged at 18,000 rpm for 25 minutes. The recovered pellets were kept in storage at -40°C. The temperature of the supernatant was raised from 50°C to 95°C. The color of the solution changed as it heated. Silver nanoparticles made with *D. quercifolia* methanol extract were subjected to a UV-VIS analysis. The visible spectrum's maximum absorption was recorded at 422 nm. Ag-NPs are known to typically have an absorption peak in the 400–500 nm range (Widatalla *et al.*, 2022).

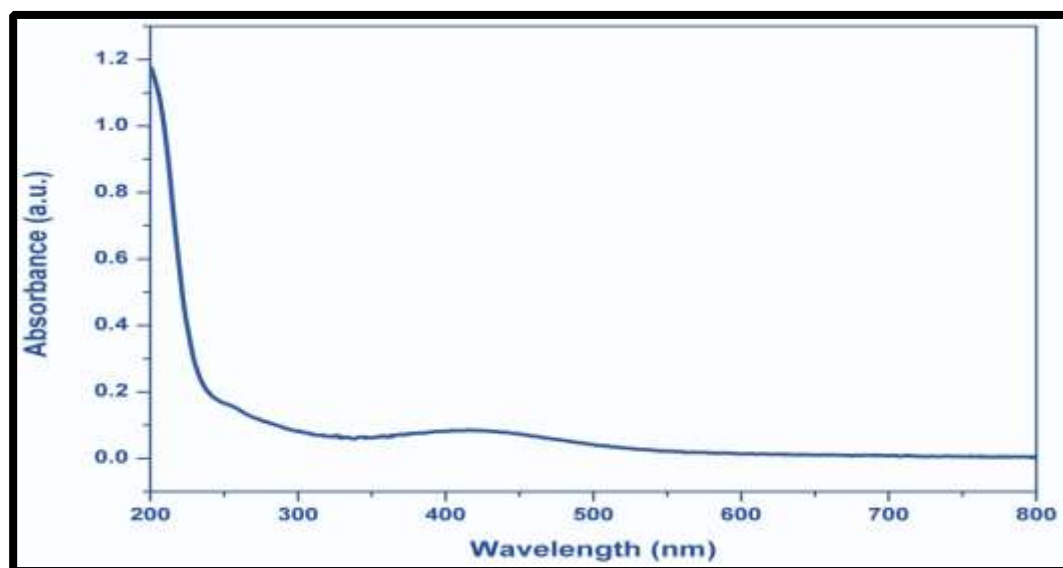


Fig. 2: UV-Visible absorption spectra of Ag-NPs

Microscopic and elemental Analysis

The size and shape of Ag-NPs extracted from an extract of *Aglaomorpha quercifolia* rhizome were assessed using a scanning electron microscope (SEM). A very tiny fraction of the silver nanoparticles was longer (Fig. 3B), and the majority were spherical in shape, with an average size of 50 nm (Fig. 3C). Curiously, the Ag-NPs generated from the methanol extract are smaller than those generated from the aqueous extract, which is consistent with earlier studies (Huang *et al.*, 2011; Yousaf *et al.*, 2020). The resulting green nanoparticles had a diameter of 60–120 nm and a median size of 70 nm. The particles have a spherical and cubic form. The average size of green nanoparticles produced from silver nitrate and aloe vera alion was 70 nm (Kumar *et al.*, 2014). The size of the nanoparticles was reported to be between 287 and 293 nm.

The lyophilized silver nanoparticles were primarily spherical particles with diameters under 100 nm,

according to scanning electron microscopy pictures (Akhil Rautela *et al.*, 2019). The shape of the nanoparticles was round and oval. While some solitary particles were discovered, most of the nanoparticles were aggregated (Suman *et al.*, 2013). Scanning electron microscopy (SEM) was used to thoroughly examine the Ag-NPs' dimensions and form. The well-defined, spherically shaped synthesized nanoparticles have an estimated cross-sectional diameter of 33 nm (Lubna *et al.*, 2023). These findings are in line with previous scholarly publications and provide credence to the consistency of the results obtained. SEM allowed for a detailed and visual assessment of the nanoparticles' structural characteristics, providing crucial details regarding their dimensions and structure that could be helpful for upcoming research and applications (Devi *et al.*, 2012; Chandran *et al.*, 2006)

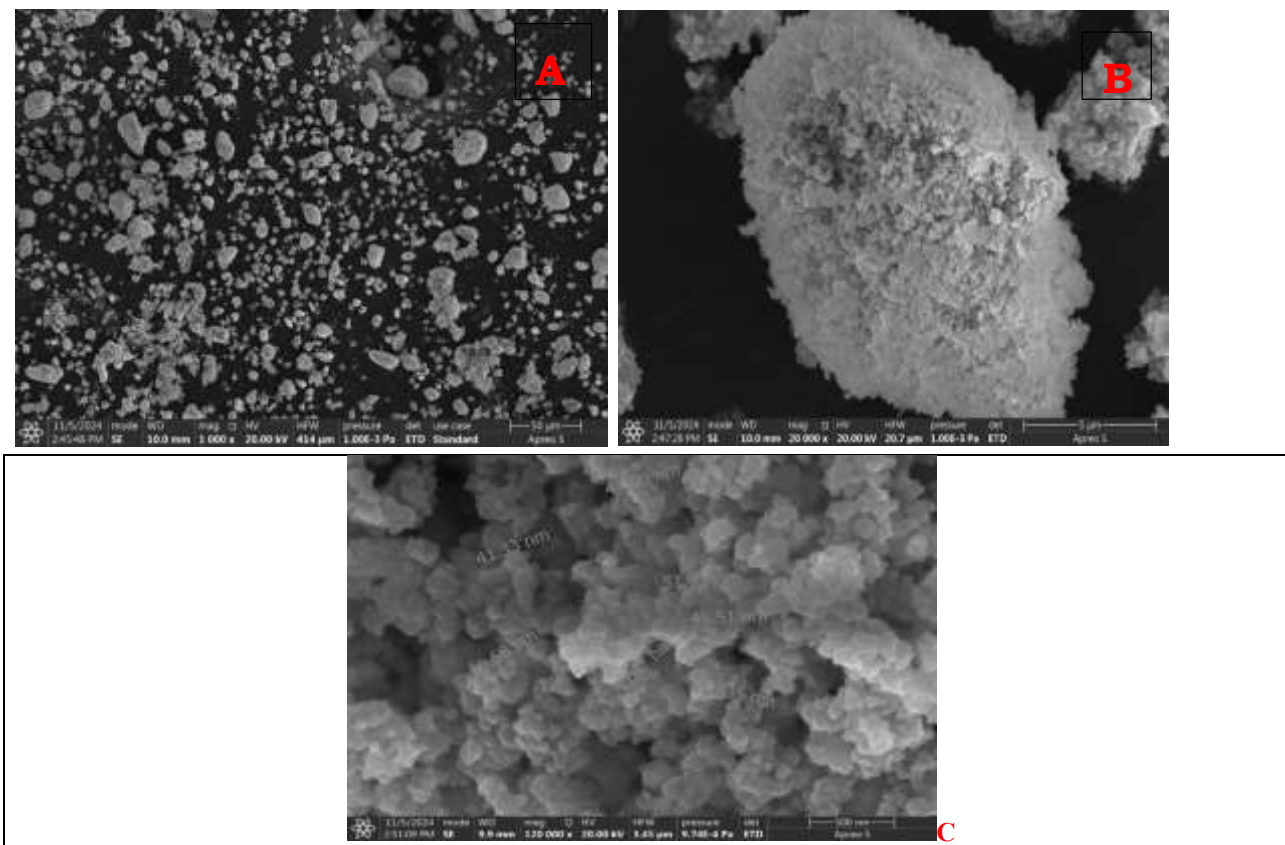


Fig. 3 SEM analysis of Ag-NPs (A-C)

Energy-dispersive X-ray (EDX) analysis

The energy dispersive spectrum of the generated nanoparticles, which shows that silver is a component element, is shown in Figure 4. Because of surface plasmon resonance, metallic silver nanoparticles usually show a notable signal peak at 3 keV (Magudapatty *et al.*, 2001; Kaviya *et al.*, 2011). EDX was utilized to validate the elemental analysis of Ag-NPs. A notable peak signal was detected at 3 KeV, which is typical of metallic silver nanoparticle absorption. An EDX detector combined with a SEM was used to confirm the elemental composition of AgNPs. Ag-NPs'

SPR absorbed metallic silver nano crystallites, resulting in strong silver (Ag) spectral peaks at roughly 3 keV in the energy dispersive spectra. Due to SPR, Ag-NPs have a characteristic optical absorption peak at roughly 3 keV (Magudapatty *et al.*, 2001). Interestingly, the signal is stronger in Ag-NPs made from *V. grandiflorum* leaf extract in methanol, suggesting that the Ag-NPs are purer in this instance. These results are in line with those of a prior work on Ag-NPs generated by *Curcuma longa*, which found a high signal for Ag and a characteristic absorption peak at 3 keV (Sathishkumar *et al.*, 2010).

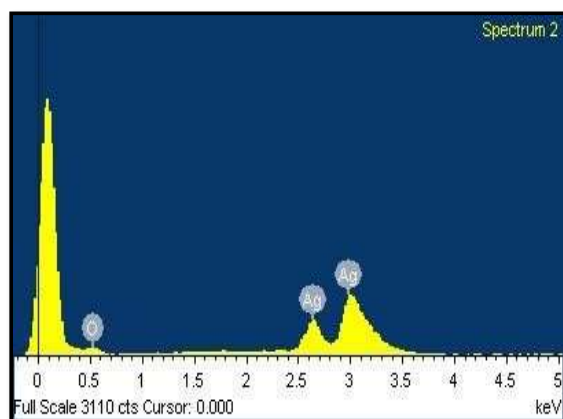


Fig. 4: EDX images of Ag NPs via *Aglaomorpha quercifolia*

FTIR analysis of Ag NPs

The specific components of compounds, as well as their chemical structure, interactions with other substances, functional groups, and bonding topologies, may all be identified and seen thanks to the incredibly accurate analytical method known as FTIR. Ag-NPs are analysed using FTIR to determine which chemicals serve as stabilizing and coating agents and to gauge the amount of silver ion reduction. The FTIR spectrum (Fig. 5) indicates that the Ag NP reduced or capped during green synthesis may have originated from carboxylic acids and amide bonding. This spectrum has several bands close to 3419, 1650, and 1489 cm^{-1} . The bands that appear at 3419 cm^{-1} , 1650 cm^{-1} , and 1489 cm^{-1} reflect the O-H band of primary amines, whereas the bands at 1489 cm^{-1} indicate the N-H band. An essential tool for comprehending the role of functional groups in the interactions between metal particles and biomolecules is

FTIR (Janakiraman *et al.*, 2011) Three primary ingredients are required for the chemical production of Ag-NPs: a silver salt, a reducing agent to convert ions into 0-charged molecules, and a stabilizing or capping agent to regulate the NPs' growth and stop them from aggregating. The many phytochemicals would function as reducing, stabilizing, and capping agents all at once in this situation. The bio fabrication of silver nanoparticles facilitated by plant extracts is well demonstrated by the FTIR spectrum. In the production of Ag-NPs, the FTIR spectra of the rhizome extracts of *Z. officinale* and *C. longa* revealed a significant absorption peak at 1387 cm^{-1} (Logeswari *et al.*, 2015) According to a report, there was an absorption peak at 1055 cm^{-1} , which could have been caused by the amine (N-H) and -C=O groups vibrating (Jyoti *et al.*, 2020; Kalaimurugan *et al.*, 2019).

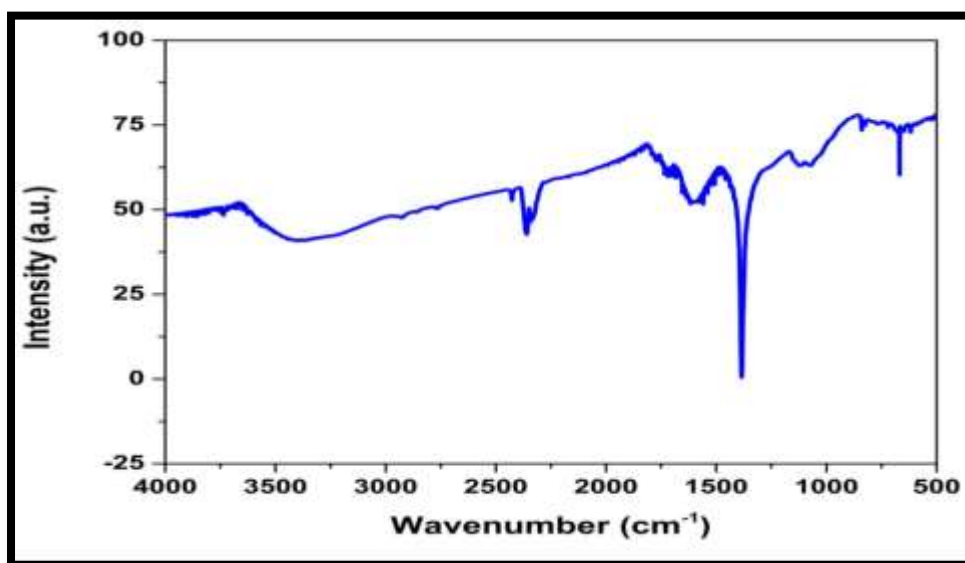


Fig.5: FTIR spectrum of prepared Ag NPs using *Aglaomorpha quercifolia*

X-ray diffraction analysis of Ag NPs

The XRD peak characteristics of the Ag-NPs produced with the green method are shown in Figure 6. Ag NPs have a face-centered cubic structure with (111), (200), (220), and (311) facets, respectively. The XRD spectrum shows these peaks at 2θ angles of 38° , 44.1° , 64.4° , and 77.4° . These diffraction peaks coincide with those of normal Ag crystals, indicating the crystalline nature of the generated Ag-NPs. These results show a strong correlation with earlier studies on Ag NP. The absence of assigned maxima in the XRD spectrum suggests that plant phytochemicals crystallized on the surface of Ag-NPs during the extraction of the *Aglaomorpha quercifolia* rhizome extract.

The XRD patterns of silver nanoparticles produced by synthesized Ag-NPs mediated by *Aglaomorpha quercifolia* rhizome extract. The anticipated average crystallite size for AgNPs was 15.07 nm. Researchers can follow green chemistry standards and use less energy for synthesis by operating at temperatures, pressures, and pH levels similar to those present in the ambient environment. This approach can increase

nanoparticle properties such as crystallinity, stability, size, and form. Living organisms produce biomolecules, including proteins, polysaccharides, lipids, and nucleic acids, as well as small natural molecules like primary and secondary metabolites. These molecules can convert the positive oxidation state of silver ions (Ag^+) into the zero-oxidation state of atoms (Ag^0), resulting in the formation of nanosilver particles in colloidal dispersions of Ag-NPs (Delgado-Beleño *et al.*, 2018). Additionally, two unassigned peaks found at 32.25° and 46.21° . These peaks were weaker than those for silver. XRD pattern of silver nanoparticles, confirming the crystalline structure of Ag-NPs. Four different diffraction peaks at 2θ values of 38.05° , 44.23° , 64.41° , and 76.66° correspond to the (1 1 1), (2 0 0), (2 2 0), and (3 1 1) reflection planes of silver's facecentered cubic structure. Additional peaks at 27.77° , 32.18° , 46.17° , and 54.752° were detected alongside the Bragg peaks of silver nanocrystals. The presence of these peaks was owing to seed extract, which contains organic chemicals and is responsible for silver ion reduction and nanoparticle stabilization (Akhil Rautela *et al.*, 2019).

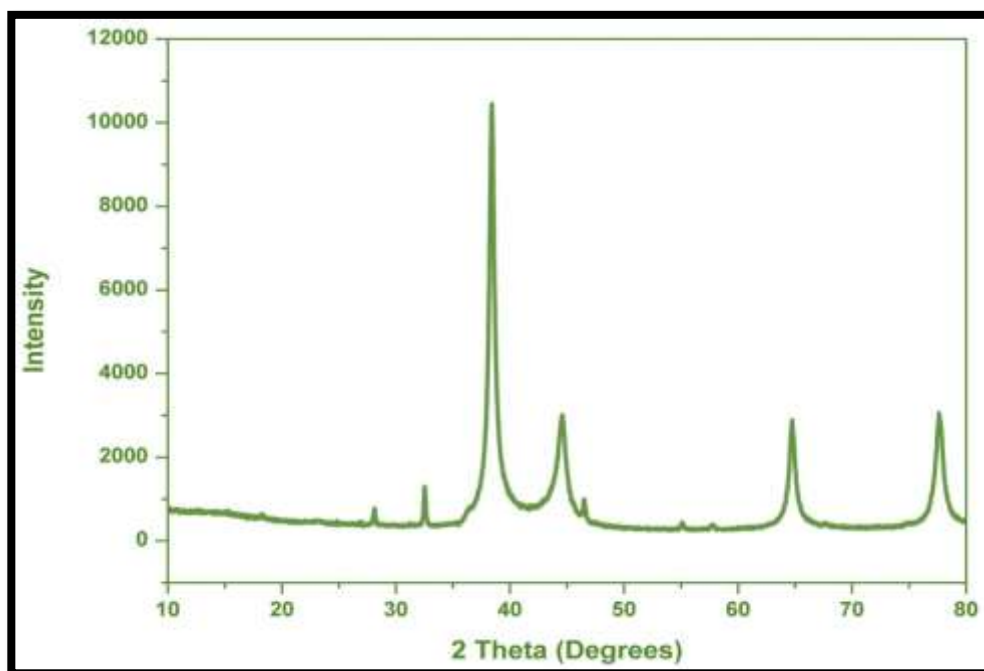


Fig.6: XRD arrangement of silver nanoparticles produced via extract from

Aglaomorpha quercifolia

Conclusion

An environmentally safe and sustainable substitute for traditional chemical and physical processes is the green production of nanoparticles utilizing plant extracts. This method makes use of the natural phytochemicals present in plants, including terpenoids, alkaloids, flavonoids, and tannins, which serve as capping, stabilizing, and reducing agents when nanoparticles are forming. The procedure is easy to understand, cost-effective, and eliminates the need for harmful chemicals, lowering environmental and health hazards. Herbs have historically been used to treat a variety of illnesses and infections in traditional medical systems like Ayurveda, Traditional Chinese Medicine, and Unani. Because of

their innate antibacterial and antioxidant qualities, these plants have also been used as natural food preservatives. This dual function highlights their adaptability and the wide range of bioactive substances they contain. The combination of herbal medicine with nanotechnology has created new opportunities to improve the therapeutic effectiveness of medicinal plants in recent years. One excellent illustration of this innovation is the use of plant extracts to create silver nanoparticles (Ag-NPs). These nanoparticles have strong antibacterial and antioxidant effects, among other amazing biological characteristics. They are especially notable for their capacity to scavenge and inhibit free radicals, which helps shield the body against oxidative stress-induced infections and degenerative disorders. By interacting

with free radicals, Ag-NPs counteract their negative effects and stop tissue and cellular damage.

In conclusion, a sustainable way to create nanoparticles with exceptional biological activity is by the green synthesis of silver nanoparticles from *Aglaomorpha quercifolia* rhizome. Significant antibacterial, anticancer, antioxidant, and anti-inflammatory qualities were displayed by the produced Ag-NPs, indicating their potential for usage in a range of therapeutic applications. Green-synthesized Ag-NPs are positioned as a viable resource for upcoming biomedical and pharmaceutical applications due to their environmentally friendly synthesis procedure and promising biological activity. To completely investigate the mechanisms underlying the biological actions of these nanoparticles and optimize the production process, more research is required.

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