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GINGER (ZINGIBER OFFICINALE) RHIZOME EXTRACT-MEDIATED GREEN SYNTHESIS OF SILVER NANOPARTICLES AND ITS CHARACTERIZATION

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ABSTRACT

The utilization of medicinal plants for synthesizing nanomaterials is gaining momentum due to its environmentally friendly characteristics and cost-effectiveness. In the present study, silver nanoparticles (AgNPs) were synthesised by utilising the rhizome extract of *Zingiber officinale* as a reducing and stabilising agent. The synthesis involved mixing a 1mM silver nitrate solution with an aqueous extract of ginger rhizome in a ratio of 10:1 under constant stirring at a temperature of 80^{o}C. The resulting AgNPs were characterized using UV-visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), and Scanning Electron Microscopy (SEM). The AgNPs exhibited a dark brown color with maximum absorbance observed at 427 nm. The FTIR spectrum displayed strong and distinctive peaks at 3339, 3250, 2124, 2072 and 1632 cm^{-1}, indicating the involvement of biomolecules in capping and stabilizing the particles. These nanoparticles exhibited a spherical shape with sizes ranging from 10-100 nm.

KEYWORDS: Silver nanoparticles, *Zingiber officinale*, Characterizations, Green synthesis.

INTRODUCTION

Nanotechnology is a multidisciplinary field that involves the manipulation and control of matter at the nanoscale, typically ranging from 1 to 100 nanometers. At this scale, materials often exhibit unique and novel properties, making them highly valuable for various applications across industries such as electronics, medicine, energy, and materials science. Nanotechnology, particularly involving metal nanoparticles, is experiencing rapid growth within the scientific and technological domains, particularly in biomedical sciences. This surge in interest is attributed to the unique optical, catalytic, electronic, magnetic, and thermal properties exhibited by metal nanoparticles.[1] Their distinctive physicochemical characteristics render them highly suitable for numerous biological applications, primarily owing to their high surface-to-volume ratio. Metallic nanoparticles find extensive biomedical applications, including antioxidant, antimicrobial, anticancer, anticoagulant, antidiabetic, and thrombolytic activities.[2,3,4,5,6,7] Although chemical and physical methods are commonly used in nanoparticle synthesis, they often involve hazardous chemicals with potential toxicity. In contrast, plant-mediated synthesis of metal nanoparticles is gaining traction due to its low toxicity, cost-effectiveness, eco-friendliness, and short processing time. Additionally, plants serve as abundant sources of bioactive secondary metabolites, such as polysaccharides, proteins, polyphenols, flavonoids, terpenoids, tannins, alkaloids, amines, ketones, and aldehydes. These compounds act as reducing, stabilizing, and capping agents during the conversion of metal ions to nanoparticles, facilitating the production of nanoparticles with desired characteristics.[8]

Silver, a non-toxic, safe, inorganic antibacterial agent, has been utilized for centuries for its ability to eliminate disease-causing microorganisms.[9,10] It possesses considerable potential for various biological applications, serving as an antibacterial agent against antibiotic-resistant bacteria, aiding in wound healing, and exerting anti-inflammatory effects.[11] Silver ions (Ag+) and their compounds are highly toxic to microorganisms, demonstrating potent biocidal effects against numerous bacterial species while exhibiting low toxicity towards animal cells. Utilizing plants for the synthesis of silver nanoparticles (AgNPs) offers an environmentally friendly and accessible method, given the widespread availability of plants and their avoidance of many costly, toxic, and harmful chemical compounds. The synthesis of AgNPs typically involves a two-step process: first, the reduction of Ag^{+} ions to Ag^{0}, followed by the agglomeration and stabilization processes that result in the formation of colloidal AgNPs. Presence of naturally occurring biomolecules, such as proteins, enzymes, tannins, phenols, sugars and flavonoids in the plant extract play a crucial role in reducing silver ions during the synthesis of AgNPs which also serve as capping agents, by adhering to the surface of AgNPs.[12] In AgNPs synthesis, the plant extract serves as both a reducing and stabilizing agent, preventing agglomeration and influencing nanoparticle morphology by controlling their growth.[13] Consequently, plant-based green synthesis methods are regarded as highly efficient routes for producing metal nanoparticles.[10]

Ginger (*Zingiber officinale*), a member of the Zingiberaceae family, stands as one of the most extensively utilized species, prevalent in various foods and beverages. Its pharmacological properties span a wide spectrum, including gastroprotective, antibacterial, anti-inflammatory, antioxidant, and anti-diabetic effects.[14,15,16,17,18,19] Throughout centuries, ginger has been a staple in traditional medicine, renowned for its efficacy in treating ailments such as nausea, vomiting, arthritis, rheumatism, muscular pains, sore throats, cramps, fever, infectious diseases, and helminthiasis.[20,21,22] Several bioactive compounds have been identified in ginger, encompassing alkaloids, shogaols, flavonoids, gingerols, and zingiberene. Its root extract harbors volatile oils such as sesquiterpenes, terpenes, geraniols, zingiberene, beta-bisabolene, terpineol, curcumin, farnesene, geranyl acetate, alpha-pinene, and limonene, along with non-volatile substances like ginerone, gingerols, paradole, and shogaols.[11] Secondary metabolites include amadaldehyde, diterpenes, gingerdiols, 6-gingerol sulfonic acid, ginger diacetates, and ginger glycolipids A, B, and C. Notable active ingredients in ginger encompass 6-gingerol, 6-shogaol, and zingiberene. Bioactive substances within ginger encompass paradol, zingiberol, zingiberone, zingerone, zingiberene, gingerol, and shogaol.[23]

In this study, environmentally friendly method was employed for the synthesis of silver nanoparticles, utilizing ginger extract as the reducing and stabilizing agents. The characterization of the silver nanoparticles was conducted through ultraviolet-visible spectroscopy (UV-Vis), Fourier Transform Infrared Spectroscopy (FTIR) and scanning electron microscopy (SEM).

MATERIALS AND METHODS

Materials

Fresh ginger rhizomes were collected from Bhandari, Wokha, Nagaland, India. Silver nitrate ($AgNO_3$) was procured from Sigma-Aldrich. All the chemicals used for the experiment were of analytical grade.

Preparation of ginger extract

The collected ginger rhizomes were thoroughly cleaned, dried and powdered (**Fig: 1**). 10 grams of powdered ginger rhizomes was mixed with 100 ml of Millipore water and kept in shaker overnight at 37^{o}C. After incubation, the plant extract was subjected to centrifugation at 5000 rpm for 10 minutes. Further, the resulting extract was filtered using Whatman No.1 filter paper and the filtrate was stored at 4°C and used within a week.

Fig. 1: Image of ginger, Powdered and Extract.

Biosynthesis of silver nanoparticles

1 mM silver nitrate ((Sigma-Aldrich) ($AgNO_3$)) solution was freshly prepared. 10 mL of plant extract was mixed with 90 mL of 1 mM silver nitrate solution under constant stirring at 80°C for 3 hours. The light-yellow color of the solution started to change gradually and turned dark brown. It was considered as a visual sign of reduction of Ag^+ to Ag^0 indicating the formation of AgNPs (**Fig: 2**). The AgNPs formation was further confirmed by using UV-Visible spectroscopy.

Characterization of biosynthesized silver nanoparticles

UV spectrum analysis was assessed using a Multi Skan Go spectrophotometer within the wavelength range of 300 nm to 800 nm at 1 nm resolution. AgNPs were additionally examined utilizing FTIR to identify the functional groups and SEM for distinguishing proof of morphology and size of biosynthesized AgNPs.

Statistical analysis

The results were analysed and were graphed using OriginPro 8.5 software.

RESULTS AND DISCUSSION

Biosynthesis of silver nanoparticles

Fresh ginger rhizomes were procured from a Bhandari, Wokha, Nagaland, India. Silver nitrate ($AgNO_3$) was procured from Sigma-Aldrich. Millipore water of analytical grade was used throughout the experiment. The AgNPs were formed within an hour of the reaction marked by a prominent change of color from light yellow to dark brown indicating that silver has been reduced. The darkening of the previously yellowish reaction mixture may be attributable to the surface plasmon resonance of the silver nanoparticles, which is regarded as the key characteristic of nanoparticle production. Most silver-synthesized nanoparticles exhibited the same colour change (**Fig 2**).[24,25,13,23,26,27,,28,29]

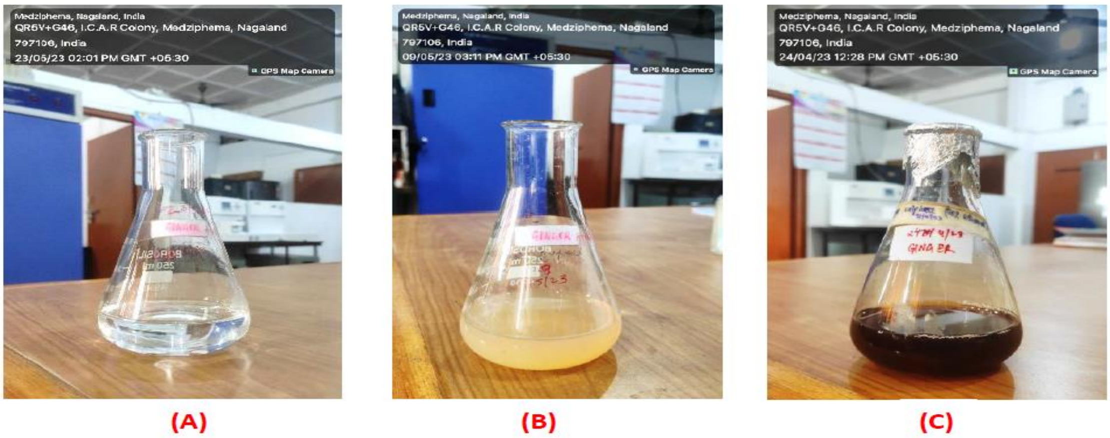

Fig. 2: Synthesis of ginger silver nanoparticles. (A) Silver nitrate solution, (B) Silver nitrate mixed with ginger extract and (C) As-synthesized AgNPs.

Characterization of the synthesized AgNPs from ginger rhizome extract

UV–visible spectra analysis

The synthesized AgNPs was confirmed by using a Multi Skan Go spectrophotometer within the wavelength range of 300 nm to 800 nm at 1 nm resolution. The UV-visible spectral analysis exhibited a characteristic surface plasmon resonance (SPR) peak of AgNPs at 427 nm **(Fig: 3**). Similar readings were observed by other researchers.[30,31,12,32]

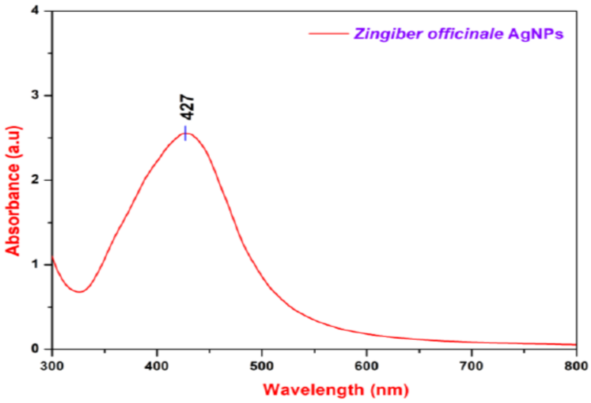

Fig. 3: UV-visible absorbance spectrum of *Zingiber officinale* AgNPs, λ_{max} = 427 nm.

Scanning Electron Microscopy (SEM)

The Scanning Electron Microscopy (SEM) analysis of AgNPs revealed at various magnifications, such as 200nm, 1 and 2 µm, show polydispersed spherical AgNps with sizes less than 100nm with diameters ranging from 10 nm to 100 nm **(Fig: 4).** This finding is consistent with several previous studies in which biosynthesized AgNps utilizing various plant entities produced spherical shaped particles.[24,25,32,33,2]

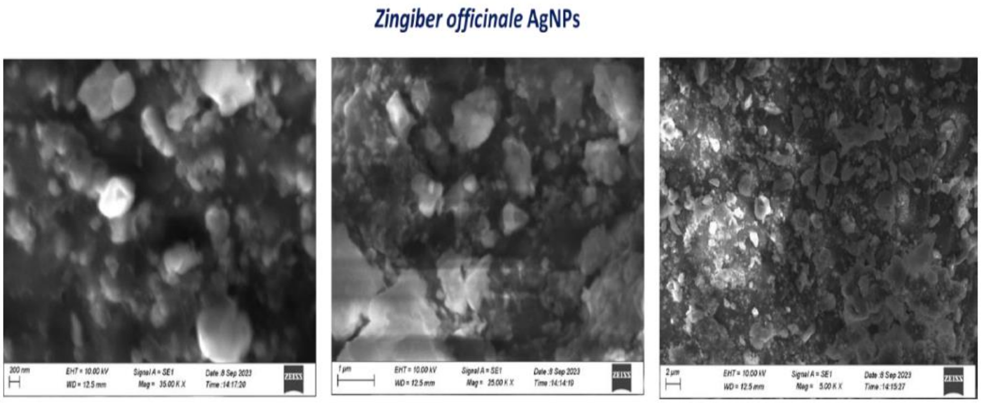

Fig. 4: SEM images of AgNPs with 200 nm, 1 µM and 2 µM resolution.

Fourier-transformed infrared (FTIR) spectroscopy

The FT-IR transmittance of AgNPs and ginger rhizome extracts reveals the probable bio-molecules involved in nanomaterial capping and efficient stability. Analysis of the FTIR spectrum of *Z. officinale* extracts (**Fig: 5**) revealed prominent peaks at 3332, 3242 cm−1 (phenolic OH stretching), 2102 cm−1 (alkyne C≡C stretching), and 1632 cm−1 (amide I C=O bond of proteins due to carbonyl stretch in proteins). Upon formation of AgNPs, distinctive peaks were observed, with shifts observed in the peaks such as 3339, 3250 cm−1 (phenolic OH stretching), 2124, 2072 cm−1 (alkyne C≡C stretching), and 1632 cm−1 (amide I C=O bond of proteins due to carbonyl stretch in proteins) (**Fig: 5**). These shifts suggest the reduction of corresponding functional groups, which likely participated in the formation of silver nanoparticles by serving as capping and stabilizing agents.[24,25,34,35,32,10,36]

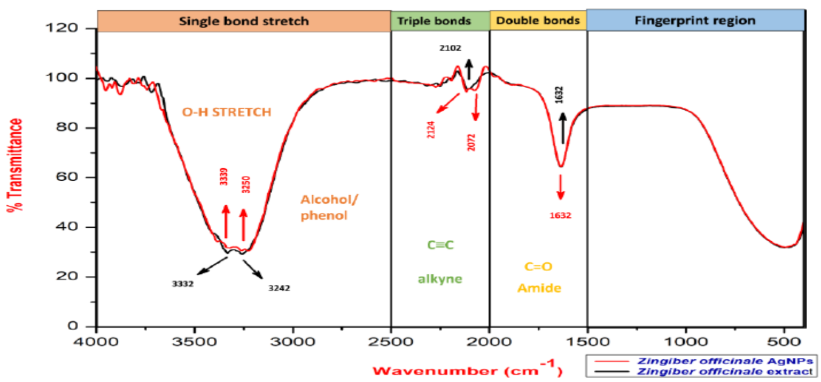

Fig. 5: FTIR spectra of ginger rhizome extract and biosynthesized AgNPs.

CONCLUSION

In this study, silver nanoparticles (AgNPs) were successfully synthesized using the extract of *Zingiber officinale* rhizome as a novel bio-reduction agent. The utilization of ginger rhizome for large-scale production of AgNPs in nanotechnology industries is environmentally sustainable and cost-effective. The procedure was relatively easy, rapid, inexpensive, eco-friendly and did not require any addition of other toxic reagents. Further experiments are needed in order to determine the atoms in the functional groups that are involved in the binding and stability of AgNPs. This environmentally friendly, green-synthesized AgNPs hold promise for diverse biomedical applications.

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