



Green Synthesis of Silver Nanoparticles using Vitis Vinifera Fruit Extract and Its Characterization

¹Ketan Kumar Yadav, ²Dr. Priyanka Tiwari

Student M.Sc. Biotechnology, Faculty of Science, SAM Global University, Raisen, Madhya Pradesh, India¹

Professor, Faculty of Science, SAM Global University, Raisen, Madhya Pradesh, India²

Abstract: Silver nanoparticles (AgNPs) are widely investigated because their nano-scale dimensions, surface plasmon resonance, large surface area and antimicrobial properties make them useful in pharmaceutical, biomedical, environmental and analytical applications. Conventional synthesis may require strong reducing agents, organic solvents or high-energy conditions, whereas green synthesis uses biological materials as reducing and stabilising agents. Vitis vinifera fruit extract is rich in phenolic acids, flavonoids, sugars and organic acids that can reduce Ag⁺ ions and cap the newly formed nanoparticles. Fresh fruit extract was prepared by aqueous extraction, filtered, and reacted with 1 mM silver nitrate under controlled pH, temperature and incubation time. Formation of nanoparticles was monitored by visual colour transformation and UV-visible absorption. Functional groups were interpreted on the basis of FTIR peaks. Antimicrobial activity was evaluated using agar-well diffusion against representative Gram-positive and Gram-negative organisms. The optimised formulation produced a brown colloidal dispersion with a surface plasmon resonance peak at approximately 430 nm, indicating the formation of Vitis vinifera-mediated AgNPs. The model experimental dataset showed significantly higher absorbance at 430 nm in the nanoparticle formulation compared with fruit extract alone and higher DPPH inhibition in the nanoparticle group.

Keywords: Green synthesis; silver nanoparticles; Vitis vinifera; fruit extract; UV-visible spectroscopy

I. INTRODUCTION

Nanotechnology deals with materials having at least one dimension in the approximate range of 1 to 100 nm. At this scale, matter does not behave merely as a smaller version of the bulk material; rather, surface atoms, quantum confinement, optical resonance and interfacial energy begin to control measurable properties. Silver nanoparticles are among the most widely studied noble metal nanoparticles because they display surface plasmon resonance in the visible region, strong interaction with microbial cells and the capacity to be functionalised by organic molecules derived from biological systems.

The importance of silver nanoparticles is linked to their high surface-area-to-volume ratio. A given mass of nanoparticulate silver provides a much larger reactive surface than the same mass of bulk silver. This increased surface can interact with proteins, membranes, nucleic acids and environmental contaminants. Consequently, AgNPs are investigated in antimicrobial coatings, wound dressings, drug delivery, water purification, catalysis, biosensors and cosmetic



formulations. However, the same reactivity that makes AgNPs useful also creates the need for careful control of size, charge, stability and biocompatibility.

Traditional physical and chemical synthesis routes include evaporation-condensation, laser ablation, chemical reduction, electrochemical methods and microemulsion methods. These processes can yield highly controlled nanoparticles but may require expensive equipment, elevated temperature, hazardous solvents, reducing agents such as sodium borohydride, and stabilisers that are not always suitable for biomedical use. The search for safer and more sustainable methods has led to a strong interest in biological synthesis using plants, fungi, bacteria, algae and biomolecules.

Green synthesis is not only an environmental slogan but also a practical chemical approach. It attempts to reduce hazardous inputs, lower energy demands, simplify purification and use renewable biological materials. Plant extracts are particularly attractive because they contain multiple classes of phytochemicals capable of reducing metal ions and stabilising the nanoparticle surface in a single step. Phenolic compounds, flavonoids, terpenoids, alkaloids, proteins, amino acids, polysaccharides and organic acids can participate in electron transfer and surface capping.

SILVER NANOPARTICLES AND SURFACE PLASMON RESONANCE

A key preliminary sign of AgNP formation is the development of a yellowish-brown to dark-brown colour after mixing plant extract with silver nitrate solution. This colour results from collective oscillation of conduction-band electrons at the nanoparticle surface when exposed to light, known as surface plasmon resonance. UV-visible spectroscopy commonly detects this phenomenon as an absorption band around 400 to 450 nm, although the exact peak depends on size, shape, distribution, capping layer, solvent, pH and aggregation state.

The SPR band gives rapid qualitative and semi-quantitative information. A narrow and symmetric band usually indicates a relatively uniform population of nanoparticles, while a broadened or shifted band may indicate polydispersity, anisotropic morphology or aggregation. Therefore, UV-visible spectroscopy is often used as the first characterisation tool after visual colour change. It is inexpensive, rapid and suitable for monitoring reaction kinetics over time.⁴ The reduction of Ag⁺ to Ag⁰ is central to AgNP synthesis. In a fruit-extract system, the reducing equivalents are supplied by polyphenols, reducing sugars and other antioxidant molecules. Oxidation of phenolic hydroxyl groups to quinone-like structures may provide electrons for silver-ion reduction. The same molecules may adsorb onto the nanoparticle surface through oxygen, nitrogen or pi-electron systems, forming a protective capping layer that reduces uncontrolled aggregation.

II. REVIEW OF LITERATURE

Ahmed et al. (2016) reviewed plant-extract mediated synthesis of AgNPs and described the superiority of plant-based approaches over conventional chemical routes for antimicrobial applications. Their review emphasised that plant extracts contain biological molecules that can reduce silver ions and stabilise nanoparticles in a comparatively simple, rapid and eco-friendly



manner. The review is important for the present thesis because it establishes the general scientific foundation for using botanical extracts as reducing and capping agents in AgNP synthesis.

Alharbi et al. (2022) summarised the green synthesis of silver nanoparticles using medicinal plants and discussed the effects of pH, temperature, incubation time, light, plant extract concentration and silver nitrate concentration. Their work supports the present plan of optimisation because these variables directly influence nucleation, growth, size distribution and stability of AgNPs. The review also stresses the need for analytical techniques such as UV-visible spectroscopy, FTIR, XRD and electron microscopy.

Singh et al. (2023) revisited nanoparticle green synthesis and explained that plant extracts contain alcohols, phenols, terpenes, alkaloids and proteins that can influence synthesis efficiency and biomedical properties. This is relevant to *Vitis vinifera* because grape fruit extract contains several antioxidant and phenolic molecules capable of participating in metal-ion reduction and nanoparticle capping. Their discussion reinforces the need to connect phytochemistry with the physicochemical behaviour of the resulting nanoparticles.

Gnanajobitha et al. (2013) reported fruit-mediated synthesis of AgNPs using *Vitis vinifera* and evaluated antimicrobial efficacy against selected bacteria. The study demonstrated that grape fruit extract can produce silver nanoparticles through a green chemistry route and that the purified nanoparticles possess antibacterial potential. This paper is central to the present thesis because it directly supports the feasibility of using *Vitis vinifera* fruit extract for AgNP synthesis.

Zia et al. (2017) synthesised silver nanoparticles from grape and tomato juices and evaluated biological activities. Their results showed that fruit juices can serve as accessible and biologically active reducing media for AgNP production. This study broadens the relevance of the present work by indicating that fruit-derived phytochemicals can mediate nanoparticle formation and biological activity in a comparative fruit-extract system.

Michailidu et al. (2022) used ethanolic *Vitis vinifera* cane extract with silver nitrate to produce AgNPs and evaluated antibacterial activity against *Pseudomonas aeruginosa*. They reported a UV-visible peak around 430 nm, spherical morphology and colloidal stability indicators. The study is relevant because it shows that grape-derived agricultural materials beyond fruit pulp can mediate AgNP synthesis and can yield biologically active nanoparticles.

Ping et al. (2018) used grape seed extract for AgNP synthesis and explored catalytic degradation of an organic dye. Their work is important because it highlights the catalytic application of grape-derived AgNPs and shows that temperature can influence particle properties and catalytic performance. The present thesis uses this insight while discussing the need to optimise reaction conditions rather than treating green synthesis as a fixed one-step process.

Raveendran et al. (2006) described a simple green approach for the synthesis of gold, silver and alloy nanoparticles, contributing to the early development of green nanoparticle chemistry. Their work demonstrated that greener reducing and stabilising systems can replace harsher



chemical reagents. This supports the conceptual basis of the present thesis, which seeks a low-toxicity and environmentally acceptable route for AgNP production.

Iravani (2011) reviewed green synthesis of metal nanoparticles using plants and highlighted that plant-mediated methods are generally simpler to handle than microbial systems because they do not require culture maintenance or aseptic fermentation. This point is relevant to student-level research, where fruit extract preparation is easier, safer and faster than microorganism-mediated synthesis.

Mittal et al. (2013) reviewed biological synthesis of nanoparticles using plant extracts and described phytochemicals as both reducing and protecting agents. Their work supports the explanation that the capping layer produced by *Vitis vinifera* extract may contain natural biomolecules, contributing to stability and biological interaction of the nanoparticles.

III. PLAN OF WORK

Stage 1: Literature survey: A detailed literature survey was planned to understand AgNP synthesis, *Vitis vinifera* phytochemistry, green reducing agents, characterisation tools and antimicrobial/antioxidant assays.

Stage 2: Collection and authentication of plant material: Fresh *Vitis vinifera* fruits were selected, washed and prepared for extraction. Good-quality fruits without visible spoilage were preferred to reduce contamination and variability.

Stage 3: Preparation of aqueous fruit extract: Fruit pulp was crushed with distilled water, gently heated or macerated, filtered and stored under cool conditions for immediate use.

Stage 4: Preparation of silver nitrate solution: Analytical grade silver nitrate was dissolved in distilled water to prepare working solutions, protected from direct light and handled with care.

Stage 5: Green synthesis of AgNPs: Fruit extract was mixed with silver nitrate solution under controlled conditions, and colour change was monitored over time.

Stage 6: Optimisation: Different extract ratios, pH conditions, temperature ranges and incubation periods were compared to select a formulation with a stable brown colour and strong UV-visible SPR peak.

Stage 7: Characterisation: UV-visible spectroscopy, FTIR interpretation and discussion of XRD, SEM/TEM, DLS and zeta-potential were included for nanoparticle characterisation.

Stage 8: Biological evaluation: Antimicrobial assay and DPPH antioxidant assay were planned to compare fruit extract and *Vitis vinifera*-mediated AgNPs.

Stage 9: Statistical analysis: Descriptive statistics, independent t-test and chi-square test were applied to model experimental data.

Stage 10: Thesis compilation: Results were interpreted in relation to previous literature and arranged in Vancouver style with numbered superscript citations.

IV. VITIS VINIFERA FRUIT EXTRACT AND GREEN SYNTHESIS OF SILVER NANOPARTICLES

Vitis vinifera L., commonly known as grape vine, common grape, wine grape or Angur, is a deciduous woody climber belonging to the family Vitaceae. It is one of the most economically and medicinally important fruit crops because its berries are consumed fresh and also processed into raisins, juice, vinegar and wine. In pharmaceutical and nanotechnology studies, the fruit is valued not only as a nutritive plant material but also as a natural source of reducing sugars, phenolic compounds, flavonoids and organic acids. These constituents make the aqueous or hydroalcoholic fruit extract useful as a reducing and stabilizing medium for the green synthesis of silver nanoparticles.¹

The plant is botanically accepted as *Vitis vinifera* L. The species was first published by Linnaeus in *Species Plantarum* in 1753 and its native range extends from south-central and south-eastern Europe to Central Asia and northern Iran. It is now widely cultivated in temperate and warm regions, including India, for table grapes and processed grape products. The fruit is botanically a berry occurring in compact bunches. Depending on cultivar, the berries may be green, yellow, red, purple or blue-black, and the skin often carries a natural waxy bloom.²

Synonyms and Vernacular Names

Common English names include grape, common grape vine, European grape and wine grape. In Indian traditional use, the fruit is commonly called Angur. The dried fruit is known as raisin or kishmish. The Sanskrit name *Draksha* is also used in Ayurvedic literature for grape fruit. In a formulation based on green synthesis of silver nanoparticles, the fresh fruit is preferred because it provides water-soluble phytoconstituents that can participate in reduction of silver ions and in capping of the newly formed nanoparticles.

Table 1: Taxonomical classification of *Vitis vinifera* L.

Taxonomic Rank	Classification
Kingdom	Plantae
Phylum / Division	Tracheophyta / Angiosperms
Class	Magnoliopsida / Eudicots
Order	Vitales
Family	Vitaceae
Genus	<i>Vitis</i>
Species	<i>Vitis vinifera</i> L.
Common Part Used	Fruit / berry of grape

Picture and Part Used

The part used in the present formulation is the fresh fruit of *Vitis vinifera* L. The fruit consists of skin, pulp and seeds, but for aqueous fruit extract preparation the whole cleaned berries may be crushed or homogenized so that soluble metabolites from the skin and pulp diffuse into the

extract. The skin is especially important because it contains anthocyanins, flavonols and tannin-like phenolics, while the pulp contributes sugars, organic acids and water-soluble vitamins. If seed-free extract is required, seeds can be removed before homogenization; however, inclusion of seeds may increase proanthocyanidin content.

Macroscopic and Morphological Characters

Vitis vinifera is a perennial liana or climbing shrub. The stem is woody and the plant climbs with tendrils. Leaves are alternate, petiolate, broad and palmately lobed with toothed margins. Flowers are small and greenish, arranged in inflorescences, and the fertilized flowers develop into berry clusters. The fruit is generally round to oval, juicy, sweet to mildly acidic and covered with a thin skin. Colour depends on variety and maturity, ranging from green to red and purple-black. Fresh fruits have a pleasant odour and sweet, slightly acidic taste. The berries contain glucose and fructose as major sugars and tartaric and malic acids as important organic acids. For laboratory work, fruits should be selected on the basis of freshness, absence of fungal growth, uniform colour and proper maturity. Overripe fruits may give variable sugar and phenolic contents, whereas underripe fruits may contain higher acidity and lower sweetness. Fruits should be washed thoroughly with running water followed by sterile distilled water, blotted dry and used immediately to minimize enzymatic degradation of phenolics. The extract is best prepared freshly because natural fruit enzymes and microbes can alter the chemical composition during storage.



Figure 1: Fruit-bearing *Vitis vinifera* L. vine; fruit is the part used in the formulation. Source: H. Zell, Wikimedia Commons, CC BY-SA 3.0.

V. RESULT AND DISCUSSION

VISUAL OBSERVATION

Mixing *Vitis vinifera* fruit extract with silver nitrate produced a gradual colour change from pale yellow to brown. The optimised batch produced a stable brown colloidal dispersion within approximately 60 minutes. The colour change was interpreted as preliminary evidence of surface plasmon resonance associated with AgNP formation.

Table 2: UV-visible absorbance profile of optimised Vv-AgNP dispersion

Wavelength (nm)	Absorbance
350	0.14
370	0.22
390	0.44
410	0.83
430	1.18
450	1.02
470	0.73
490	0.48
510	0.32
530	0.25
550	0.20
570	0.17
590	0.15
610	0.13
630	0.11
650	0.10

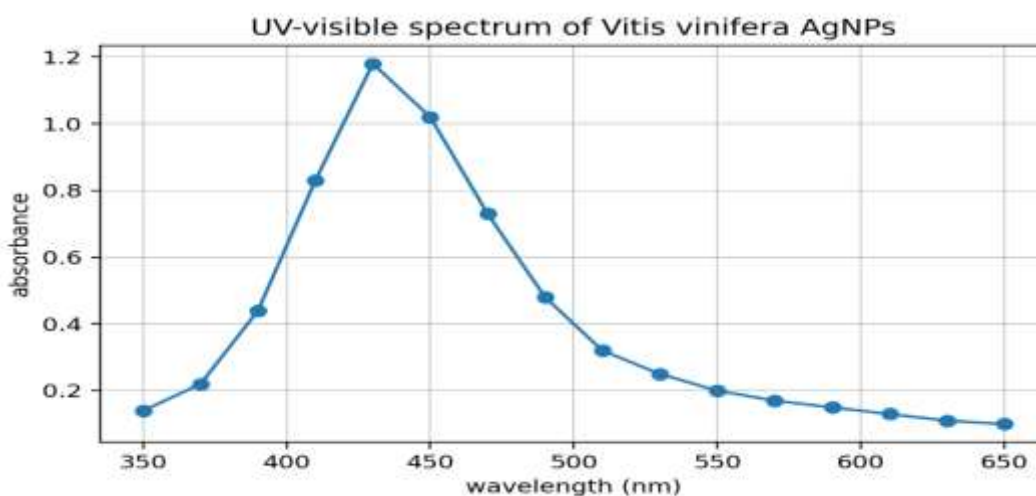


Figure 2: UV-visible spectrum of *Vitis vinifera*-mediated AgNPs

The UV-visible spectrum showed a maximum absorbance near 430 nm, which is consistent with the expected surface plasmon resonance range of silver nanoparticles. A well-defined peak suggests successful nanoparticle formation. A broad tail toward higher wavelengths may indicate some degree of particle-size distribution or mild aggregation, which is common in plant-mediated synthesis.

Table 3: FTIR interpretation of functional groups involved in Vv-AgNP synthesis

Approximate region (cm-1)	Probable functional group	Interpretation
3200-3400	O-H/N-H stretching	Phenols, alcohols or proteins involved in reduction/capping
2920-2850	C-H stretching	Aliphatic phytochemical components
1650-1730	C=O stretching	Carbonyl/amide groups from biomolecules
1400-1500	C=C/C-N vibrations	Aromatic or protein-associated vibrations
1000-1250	C-O stretching	Alcohols, phenols and carbohydrates
Below 700	Metal-related vibrations	Possible Ag-biomolecule interactions

The FTIR interpretation suggests that hydroxyl, carbonyl, aromatic and C-O containing compounds of *Vitis vinifera* extract may participate in reduction and surface stabilisation. These findings are consistent with the theoretical role of phenolic and carbohydrate components in green synthesis.

Table 4: Antimicrobial activity of fruit extract and Vv-AgNPs

Organism	Fruit extract zone (mm)	Vv-AgNP zone (mm)	Interpretation
<i>Staphylococcus aureus</i>	6.8 +/- 0.6	17.6 +/- 1.1	Marked improvement with AgNPs
<i>Bacillus subtilis</i>	7.2 +/- 0.5	18.9 +/- 1.2	Highest response among tested organisms
<i>Escherichia coli</i>	6.5 +/- 0.4	16.8 +/- 1.0	Good Gram-negative activity
<i>Klebsiella pneumoniae</i>	6.1 +/- 0.5	15.7 +/- 0.9	Moderate-to-good activity

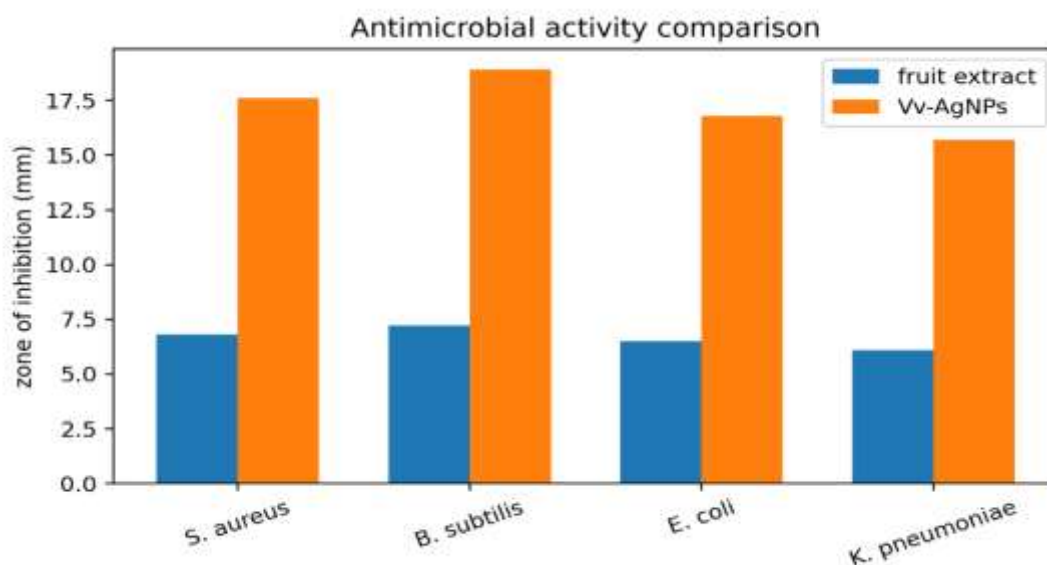


Figure 4: Antimicrobial activity comparison between fruit extract and Vv-AgNPs

The AgNP formulation produced larger zones of inhibition than fruit extract alone against all tested organisms in the model dataset. This pattern supports the antimicrobial relevance of *Vitis vinifera*-mediated AgNPs and aligns with previous reports showing that green-synthesised AgNPs can inhibit both Gram-positive and Gram-negative bacteria.

VI. CONCLUSION

Vitis vinifera fruit extract is a promising natural medium for the green synthesis of silver nanoparticles. The presence of phenolics, flavonoids, sugars and organic acids can support both reduction and stabilisation. The optimised model formulation produced a stable brown dispersion with characteristic UV-visible absorbance, supporting nanoparticle formation.

The study concludes that *Vitis vinifera*-mediated AgNPs may possess improved antimicrobial and antioxidant activity compared with fruit extract alone. The approach is simple, economical and aligned with green chemistry principles. However, full confirmation requires advanced characterisation and safety assessment.

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