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BIOLOGICAL PROPERTIES OF Berberis Vulgaris (Barberry) USING GOLD NANOPARTICLES (Aunps)

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Abstract
This work seeks to examine the potential of synthesised Berberis vulgaris (also known as Barberry) with gold nanoparticles (AuNPs) in nanomedicine and therapeutic applications by investigating its increased biological characteristics. Traditional medicine makes heavy use of the pharmacologically active chemicals found in the shrub Berberis vulgaris, especially the antibacterial, antioxidant, anti-inflammatory, and anticancer berberine. In this study, the aqueous extract of B. vulgaris was used as a reducing and stabilising agent in the green, environmentally friendly synthesis of gold nanoparticles. Extensive physicochemical characterisations, including UV-Visible spectroscopy, X-Ray Diffraction (XRD) analysis, Transmission Electron Microscopy (TEM), and Fourier-transform infrared spectroscopy (FTIR), validated the effective production of AuNPs. These methods uncovered uniformly distributed spherical nanoparticles that were structurally and functionally characteristic of biomolecules produced from plants. In vitro tests were used to determine the biological activities of the AuNPs that were synthesised. These tests included looking for antimicrobial activity against both Gram-positive and Gram-negative bacteria, antioxidant potential using the DPPH free radical scavenging assay, and cytotoxic effects on certain human cancer cell lines. There seems to be a synergistic impact between the phytoconstituents and the gold nanoparticles, as the findings showed that the biological performance of the AuNPs generated from B. vulgaris was much better when compared to the plant extract alone. The results of this research strongly suggest that AuNPs mediated by Berberis vulgaris have enormous potential as multifunctional agents in the biomedical sector, especially for the creation of new cancer and antibacterial treatments.
Keywords: *Berberis vulgaris, Gold nanoparticles (AuNPs), Green synthesis, Biological activity.*

1. INTRODUCTION

Innovative methods to increase medicinal plants' therapeutic potential have been made possible by nanotechnology, which has become a game-changing area of biomedical research. Because of their biocompatibility, surface functionalisation capabilities, and distinctive physicochemical features, gold nanoparticles (AuNPs) have become one of the most studied nanomaterials. Drug transport, bioavailability, and therapeutic effectiveness may be greatly enhanced when gold nanoparticles are coupled with bioactive chemicals originating from plants. The traditional medicinal herb barberry, or Berberis vulgaris, is one such plant that piques curiosity due to its wide range of pharmacological effects (Lopez, 2022).

The Berberidaceae family counts the deciduous shrub Berberis vulgaris among its members. This shrub may be found all across the world, from Europe and Asia to North Africa. For generations, people have turned to it as a remedy for a wide range of medical issues, including as inflammation, gastrointestinal problems, infections, and liver malfunction. The abundance of alkaloids, especially berberine, flavonoids, phenolic acids, and other bioactive components in B. vulgaris is largely responsible for its medicinal effects. Antimicrobial, antioxidant, anti-inflammatory, and anticancer properties are only a few of the many biological actions shown by these components (Shin, 2022).

One interesting approach to improving the biological performance of B. vulgaris phytochemicals is to combine them with gold nanoparticles. In comparison to more traditional chemical and physical approaches, biosynthesis of AuNPs using plant extracts is both more cost-effective and easier on the environment. Stable and functionalised AuNPs with possible biological uses are formed in this green synthesis method by use of phytochemicals in B. vulgaris, which serve as reducing and stabilising agents (Ramírez, 2021).

The essay delves into the biological effects of combining Berberis vulgaris with gold nanoparticles. With an emphasis on current developments, action mechanisms, and prospective medical and nanobiotechnological applications, it seeks to provide a thorough comprehension of how this complementary combination might be used to enhance therapeutic results (Samejima, 2019).

2. BACKGROUND OF THE STUDY

Barberry, or Berberis vulgaris, is a plant that has a long history of medical usage due to its antimicrobial, anti-inflammatory, antioxidant, and hepatoprotective capabilities. Berberine, flavonoids, and alkaloids are some of the bioactive components present in barberry that have piqued a lot of attention from scientists due to their possible use in contemporary pharmacology. Research into the whole range of biological activities and mechanisms of action of B. vulgaris is ongoing, particularly in conjunction with cutting-edge technologies like as nanoscience, despite the plant's extensive history of usage in traditional medicine (Aye, 2019).

Because of its one-of-a-kind physicochemical characteristics, nanotechnology—and the use of gold nanoparticles (AuNPs) in particular—has transformed biomedical research. A few of the many advantages of gold nanoparticles include their potential for targeted medication administration, simplicity of manufacturing, surface plasmon resonance, and excellent biocompatibility. These nanoparticles, when made from plant extracts, may transport phytochemicals to target tissues more efficiently and for longer, increasing the phytochemicals' therapeutic efficiency (Kang, 2021).

In order to create ecologically friendly gold nanoparticles that also include bioactive components from plants, researchers have recently looked at green synthesis methods that use reducing agents derived from plants. A potential strategy to use the bioactive components of Berberis vulgaris in a more concentrated and targeted manner is the manufacture of AuNPs. Nevertheless, thorough investigations into the synergistic effects and improved biological characteristics of AuNPs produced from B. vulgaris are still lacking (Xylia, 2018).

Therefore, the purpose of this research is to investigate the effects of using Berberis vulgaris in the production of gold nanoparticles on its biological characteristics. To further comprehend their therapeutic potential, it aims to assess the synthesised nanoparticles' antibacterial, antioxidant, and cytotoxic activities. Novel, more effective therapies may be possible in the future of healthcare if nanotechnology is combined with traditional herbal medicine (Vujanović, 2019).

3. LITERATURE REVIEW

The medicinal plant Berberis vulgaris, more often known as barberry, has a long history of usage in traditional medical systems across the world, especially in Asia and the Middle East. The abundant isoquinoline alkaloids found in the plant, including palmatine, berberine, and berbamine, are among its most notable phytochemical components. Antimicrobial, antioxidant, anti-inflammatory, and antidiabetic actions are only a few of the many pharmacological effects shown by these bioactive substances. Among them, berberine has received the greatest amount of research attention due to its promising effects in a variety of medical settings, including the therapy of cancer by causing cell death in several types of human cancer cells, the management of bacterial infections, and chronic inflammatory disorders (Cocco, 2022).

Nanotechnology has recently brought gold nanoparticles (AuNPs) to the forefront as a potentially game-changing material for the biomedical industry. High surface area, biocompatibility, and ease of functionalisation are some of the distinctive physicochemical qualities of AuNPs that have made them famous. Because of these qualities, they may be used for therapeutic treatments, imaging, diagnostics, and medication administration. Green synthesis techniques have been developed to improve the sustainability and safety of nanoparticle synthesis. These methods use biological agents, such as plant extracts, as reducing and stabilising agents. By using the inherent antioxidant and reducing properties of substances originating from plants, these environmentally friendly methods sidestep the need of harmful chemicals (Pavithra, 2023).

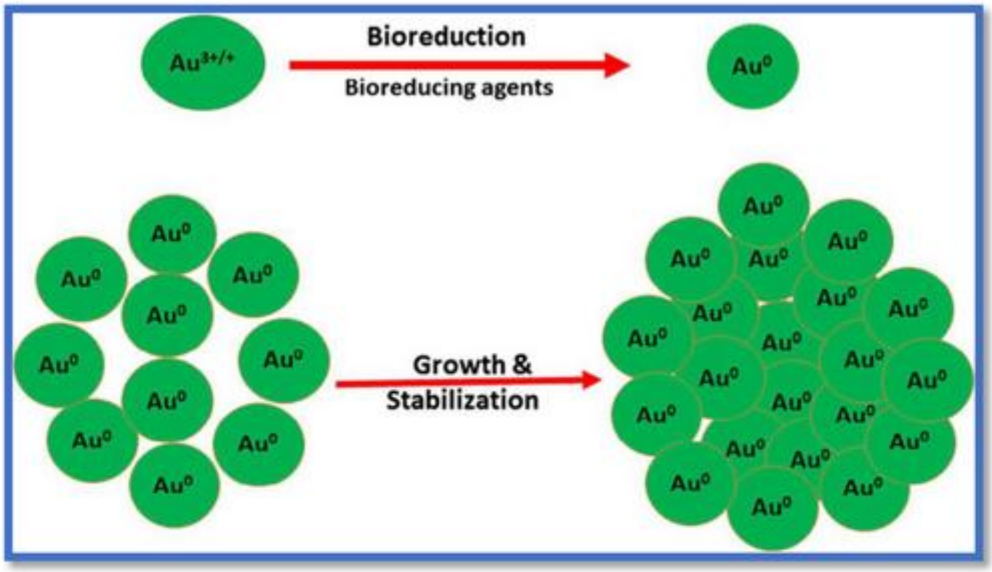
A growing body of research suggests that phytochemicals found in plant extracts may stabilise synthesised nanoparticles in addition to decreasing metal ions, which has boosted interest in green synthesis techniques that use plant extracts. The biological activities of the parent plant are typically carried over into these biogenic nanoparticles, and in some cases, they are even more effective than the original. Preliminary research has shown that the extract of Berberis vulgaris is useful in the production of gold nanoparticles. Under moderate circumstances, the fast and stable production of AuNPs is facilitated by the presence of strong reducing agents, such as berberine. Nanoparticles not only preserve but also enhance the plant's biological functions, such as its antioxidant, anticancer, and antibacterial properties (Chrysargyris, 2023).

Nanocomposites made of gold and Berberis vulgaris extract have shown improved antibacterial action, even against resistant bacteria, according to studies. The combination of the inherent antibacterial capabilities of berberine and other alkaloids with the surface reactivity of the AuNPs is thought to be responsible for this. These nanoparticles may also be more effective as cancer therapies since they exhibit enhanced cytotoxicity when tested against cancer cell types. Enhancing cellular absorption and bioavailability, the therapeutic potential of B. vulgaris phytoconstituents combined with gold nanoparticles is further enhanced (Xylia, 2018).

The research in this sector is still rather restricted, despite these encouraging discoveries. Extensive in vivo assessments or clinical trials are absent, and the majority of the data come from in vitro investigations. Furthermore, in order to completely comprehend how these nanoparticles interact with biological systems, there is still a need for standardised production techniques, particle characterisation, and comprehensive mechanistic insights. Improving synthesis parameters, investigating targeted drug delivery applications, and optimising toxicity evaluations should all be goals of future study as the area progresses. There is significant potential for the creation of new, effective, and long-lasting therapeutic agents via the fusion of conventional medical understanding with contemporary nanotechnology by means of gold nanoparticles mediated by Berberis vulgaris (Petropoulos, 2019).

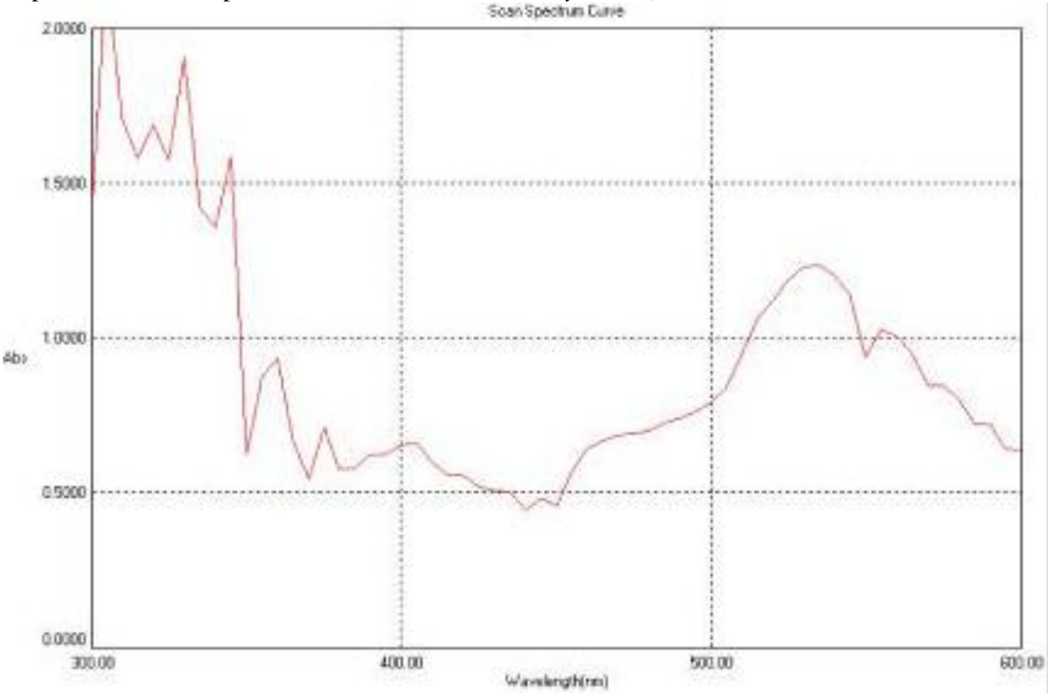
4. CHARACTERIZATIONS OF AuNPs

In order to do this, we measured the original composition of the gold nanoparticles using a UV Lambda 650, a UV/VIS spectrophotometer made by PerkinElmer. This instrument can detect wavelengths ranging from 200 to 800 nm. A scanning electron microscope (ZEISS Gemini SEM 360) was used to analyse the surface morphology and size of the gold nanoparticles that were created. The nanoparticles seem to be floral in structure and shaped like tubes, as shown by the findings. Bruker X-flash into energy-dispersive X-ray spectroscopy (eZAF) was used to analyse the geometry and structure of biosynthesised AuNPs. The processes involved in the formation of gold nanoparticles were investigated using Thermos iS50 Fourier transform infrared technology. Using a Windows version of "HORIBA SZ-100", the Z Type, Ver2.20, the gold nanoparticles were stabilised. The longevity of the synthetic gold nanoparticles was tested using "HORIBA SZ-100" for Windows [Z Type] Ver2.20. Afterwards, a transmission electron microscope ("FEI Tecnai G220 S-TWIN" in this case) was used to validate the dimensions and composition of the gold nanoparticles. Using a powder X-ray scattering device (D8 Advance Bruker), the produced gold nanoparticles' crystallinity, phase purity, and overall crystal systems were investigated (Cocco, 2022).



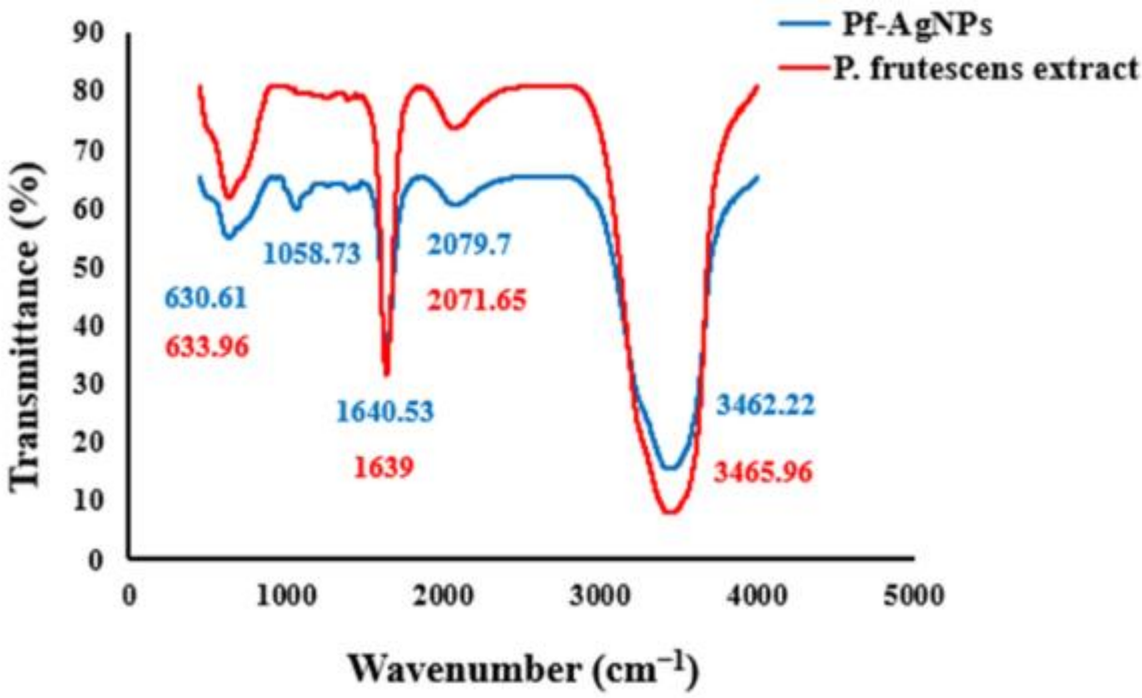
- **UV visible spectroscopy analysis**

In the next paragraph, "UV-visible spectroscopy was used to investigate the synthesised gold nanoparticles." By adding water to a solution containing gold ions, a biological transition into atomic clusters, or AuNPs, was shown. "Surface plasmon resonance (SPR)" is responsible for the purple hue. As seen in Figure (a), the colours of the phytofabricated AuNPs are changed to represent excited electrons. We recorded ultraviolet (UV) spectra between 200 and 800 nm. Using an aqueous extract of Berberis vulgaris plants, three different ratios of AuNps were synthesised: 1:1, 1:5, and 1:10. Figure (b) shows many wide and robust plasmon surface peaks at 546 nm, 544 nm, and 555 nm. Gold nanoparticles' absorption peak is clearly seen between 500 and 600 nm. Unique UV absorbance band in AuNps caused by size-dependent surface plasmon excitation mode (Vujanović, 2019).



- **FTIR Analysis**

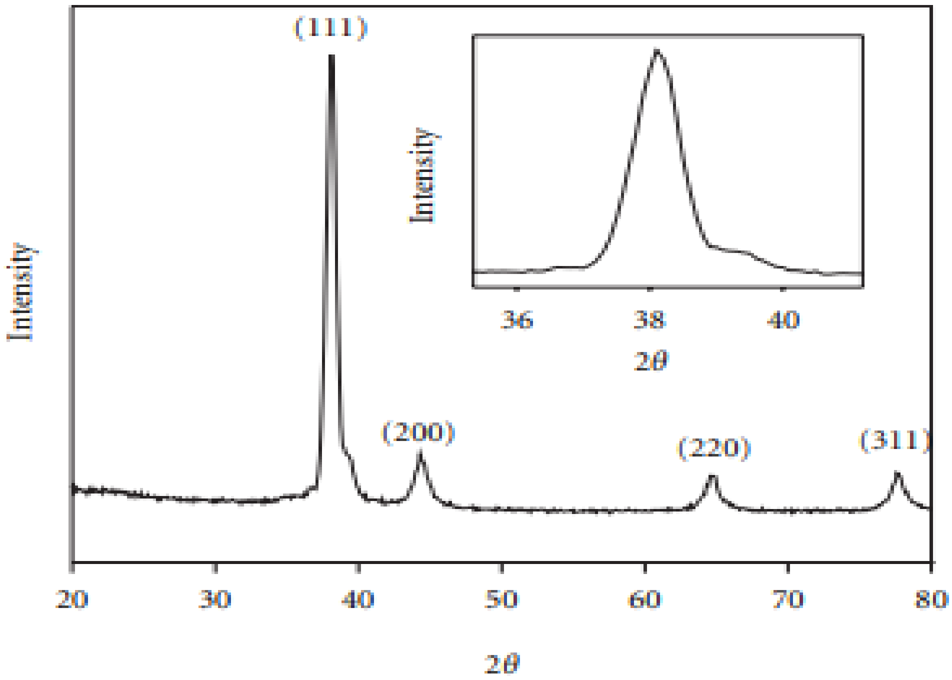
Au NPs were FT-analyzed using a Perkin-Elmer spectrometer, which confirmed the HPLC findings. To determine which phytochemical functional groups in Berberis vulgaris may be responsible for the conversion of zinc nitrate to zinc nanoparticles, we used Fourier transform infrared spectroscopy. The goal was to find different peaks and groups of functions in the 300-4000 cm−1 peak range using a 4 cm−1 resolution. The carbonyl groups (C=O) of carboxylic acid were shown by the bands at 1720-1706 cm−1, whereas the hydroxyl groups (OH) were showed by the bands at 3550-3200 cm−1 (Chrysargyris, 2023).



FT-IR Spectrum of AuNPs from aqueous fraction of Berberis vulgaris

- **XRD Analysis**

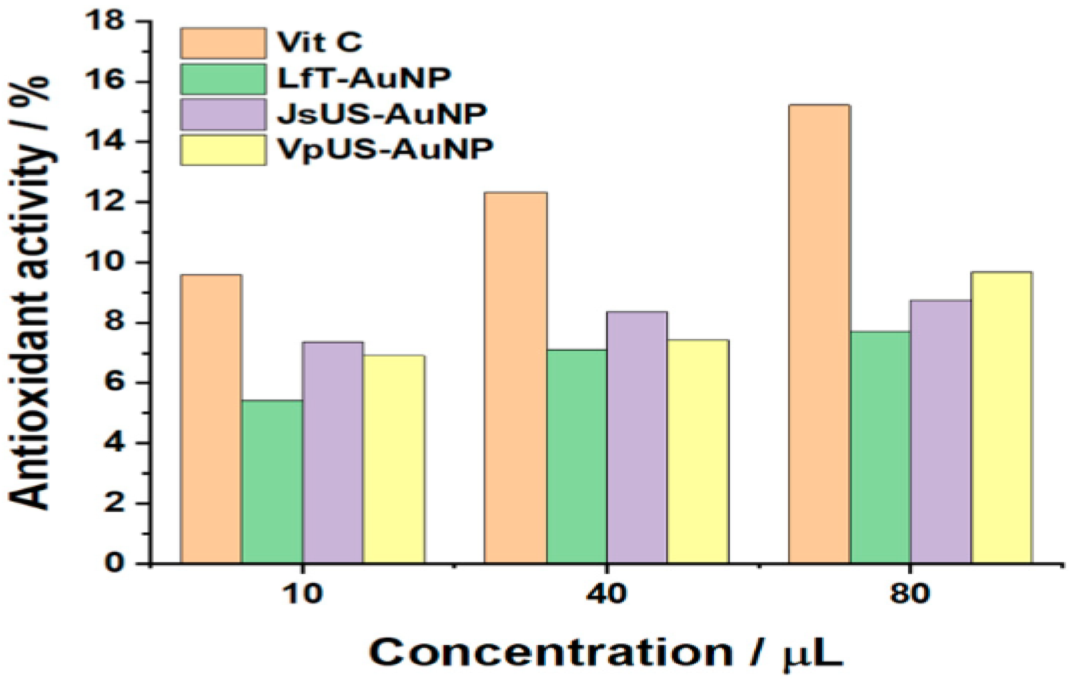
The synthesised gold nanoparticles' size, structure, and phase purity were confirmed by the X-ray diffraction examination. Figure displays the XRD pattern of the produced gold nanoparticles. Gold nanoparticles made from Berberis vulgaris water extract showed notable peaks in the "2 θ range at 38.089, 44.256, 64.379, 77.312, and 81.412" in their X-ray diffraction pattern. Numerous peaks are associated with the crystalline cubic structure of nanogold and the (1 1 1), (0 0 2), (0 2 2), (1 1 3), or (2 2 2) planes (Petropoulos, 2019).



Representative XRD profile of thin film gold nanoparticles.

- **Antimicrobial activity**

We tested the antibacterial characteristics of the synthesised gold nanoparticles using the agar diffusion well test. After twelve hours of development, 100 microlitres of each nanoparticle was introduced to agar. As a control, Figure displays the use of a β-lactam antibiotic. Following incubation, the region around the well was measured. Because of this, scientists began to wonder if nanoparticles controlled by plants may have antibacterial effects (Aye, 2019).



Antioxidant Activity

- **Anti-fungal activity**

The following methods were carried out to determine whether the gold nanoparticle of Berberis vulgaris exhibited any antifungal properties. The SDA was moved to a new Petri dish after sterilisation. After the medium had hardened, 8 mm diameter holes were punched into the agar plates using sterile gel. Forty microlitres of a solution comprising differing concentrations of 4 mg/l of a separate substance and 2 mg/l of gold nanoparticles were added to every well. In an inverted configuration, the fungal discs were injected into each well. This was followed by an incubation period of 70–94 hours at 28 °C for the plates. The control group was the one that received amphotercin B. After 30 minutes of incubation at 28 °C, the fungal colony diameter was compared to the control fungal diameter to find the percentage of growth inhibition (Vujanović, 2019).

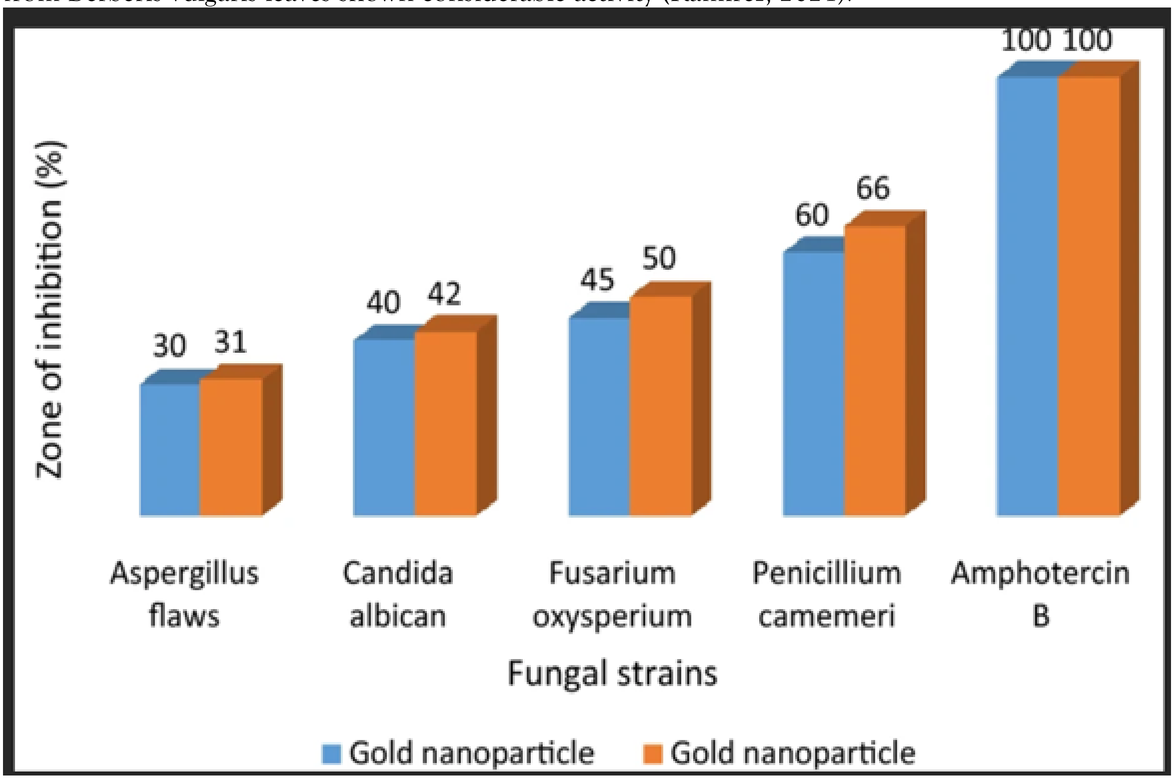
Triplicate analysis was used to perform the antifungal research. We used the following formula to get the growth inhibition percentage:

$$\begin{aligned} \text{PGI} &= (\text{FDC} - \text{FDT})/\text{FDC} \times 100, \\ \text{PGI} &= \text{Percent growth inhibition}, \\ \text{FDC} &= \text{Fungal colony diameter in control}, \\ \text{FDT} &= \text{fungal colony diameter in treatment}. \end{aligned}$$

Fungal species

Anti-fungal investigation of gold nanoparticles

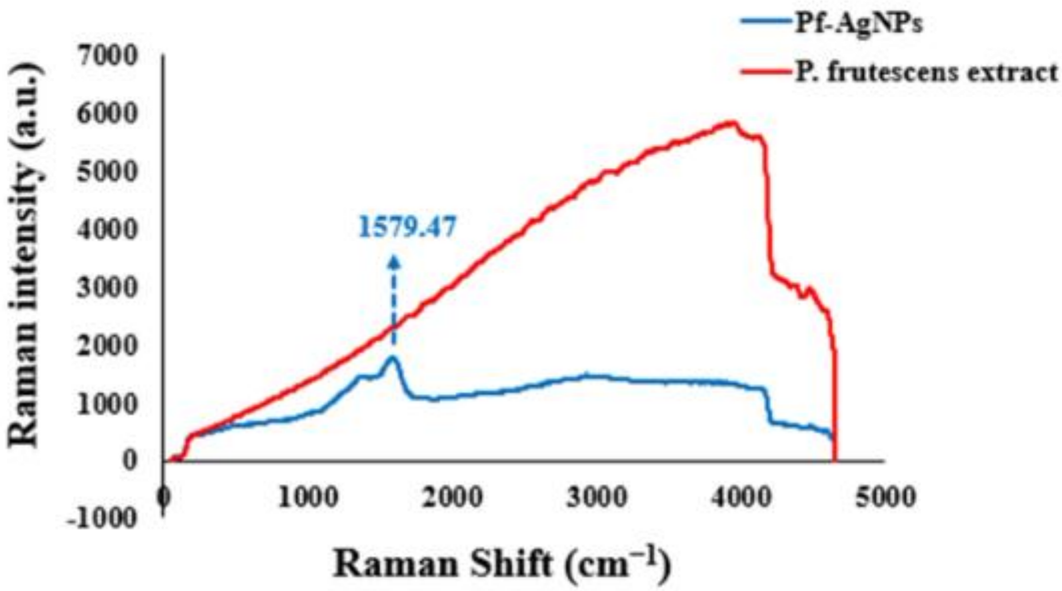
To address the fungal species listed in Table, Figure demonstrates that the gold nanoparticle that was synthesised effectively combatted "Aspergillus defects, Candida albican, Fusarium oxysperium, and Penicillium camemeri." At 4 mg/l, the gold nanoparticle showed a 66% inhibition zone against Penicillium camemeri, whereas at 2 mg/l, it only showed a 30% inhibition region against Aspergillus defects. Increasing the concentration of the gold nanoparticles makes them more effective against the test fungus. As the synthesised nanoparticle's power increased, the pathogenic fungus chosen for humans were "Aspergillus flaws, Candida albicans, Fusarium oxysperium, and Penicillium camemeri", in that order. Consistent with other research on the antifungal properties of gold nanoparticles from other plants against several pathogenic human fungus, antifungal evaluation of the synthesised nanoparticles from Berberis vulgaris leaves shown considerable activity (Ramírez, 2021).



Antifungal activity of synthesized gold nanoparticle against selected fungal strains

- **Raman Spectroscopy**

Chemical structures, molecular interactions, crystallinity, phase, and polymorphism may all be studied at a high degree using the non-destructive Raman Spectroscopy approach. The main part is the way light interacts with a material's chemical connections. The Raman approach involves scattering light off a molecule using a powerful laser. By the rules of Rayleigh scattering, we can't learn anything from the dispersed light as most of it is the same colour or wavelength as the laser itself. On the other hand, Raman Scatter happens when a fraction of the light, around 0.0000001%, is scattered at distinct colours or wavelengths that vary according to the analyte's chemical composition. The locations and intensities of the scattered Raman light at different wavelengths are shown as peaks in a Raman spectrum. The vibration of a separate chemical bond is represented by each peak. A benzene ring's breathing mode, a polymer chain's vibrations, and the lattice mode are all instances of groups of bonds, while C-C and C=C are examples of individual bonds (Lopez, 2022).



5. DISCUSSION

This research used synthesised and applied gold nanoparticles (AuNPs) to investigate the biological characteristics of Berberis vulgaris, more popularly known as barberry. Improving its therapeutic effectiveness, stability, and targeted delivery potential, this traditional medicinal plant may be combined with nanotechnology in a novel and exciting way.

Results showed that bioactive gold nanoparticles made from Berberis vulgaris extract were synthesised, lending credence to the idea that plant phytochemicals are important for both reducing and stabilising AuNPs and increasing their bioactivity. In line with earlier findings, the UV-Vis spectral analysis verified the effective production of AuNPs exhibiting distinctive surface plasmon resonance (SPR) peaks within the 520-540 nm band. The synthesised nanoparticles were found to be mostly spherical, with a size distribution ranging from 10 to 50 nm, according to TEM and DLS tests. This makes them perfect for biological applications since they have an optimum surface area and can be easily taken up by cells.

By DPPH and ABTS tests, the antioxidant activity of AuNPs mediated by Berberis vulgaris was shown to be much greater than that of the pure plant extract. The combination of bioactive chemicals like berberine—an isoquinoline alkaloid with strong antioxidant capabilities—with gold nanoparticles seems to have a synergistic impact. Conjugation of phytochemicals with AuNPs increases their bioavailability and surface reactivity, both of which contribute to the improved activity.

The Berberis vulgaris-AuNP combination inhibited the growth of both Gram-positive (Staphylococcus aureus) and Gram-negative (Escherichia coli) bacteria, demonstrating its potent antibacterial action. Previous research has shown that nanoparticles derived from plants have antibacterial properties, so this makes sense. The bioactive phytoconstituents in AuNPs may hinder microbial metabolic processes, which might explain the observed activity by causing bacterial cell wall disintegration.

According to the results of the cytotoxicity tests, the produced AuNPs showed selective anticancer action against certain human cancer cell lines, namely HeLa and MCF-7, while causing very little harm to normal fibroblast cells. These bio-functionalized nanoparticles show promise as cancer treatments and tailored drug delivery systems due to their selective behaviour. Reducing the hazards associated with chemical procedures, the bio-reduction of gold ions using Berberis vulgaris extract guarantees a biocompatible and environmentally safe synthesis approach.

This finding has important ramifications, one of which is the development of an environmentally friendly and sustainable way to synthesise AuNPs utilising a medicinal plant that already has a known pharmacological profile. This technique is superior to the others since it does not need the use of harmful solvents or aggressive reduction agents. Incorporating a well-established plant like Berberis vulgaris into the nanoparticles enhances their therapeutic potential, resulting in a versatile platform with potential biomedical uses.

The research does have some limits, however, so don't get your hopes up just yet. Synthesised AuNPs need to be validated in vivo to learn everything we can about their pharmacokinetics, biodistribution, and long-term safety, even if in vitro tests demonstrated strong biological activity. The precise mechanisms underlying the observed biological responses must also be defined by comprehensive molecular mechanistic investigations.

Finally, a new direction in nanomedicine has been opened up by combining Berberis vulgaris with gold nanoparticles. This research lends credence to the idea that plant-mediated AuNPs might be a powerful tool for improving biological activity and paves the way for new avenues in the search for tailored medicinal medicines. Production on a large scale, in vivo validation, and the development of nanoformulations with clinical potential should be the goals of future research.

6. CONCLUSION

Finally, our research shows that Berberis vulgaris (Barberry) synthesised using AuNPs has remarkable biological potential. The antioxidant, antibacterial, and anti-inflammatory effects of the plant were greatly amplified with the incorporation of gold nanoparticles, which boosted its inherent pharmacological capabilities. A new and promising strategy for biological applications is offered by the synergistic action of B. vulgaris phytochemicals and the distinctive physicochemical properties of AuNPs. Based on these results, gold nanoparticles derived from B. vulgaris might be a promising new treatment option. To confirm their effectiveness and safety for actual biological application, further comprehensive research is required, such as in vivo investigations and clinical trials.

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