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Green synthesis of metal oxide nanoparticles using datura plant root extract and their biomedical applications

PRAKRITI PAREEK* and DR. MANJUL MISHRA
**Research Scholar, Chemistry Department, Apex University, Jaipur (Rajasthan)*
Professor, Chemistry Department, Apex University, Jaipur (Rajasthan)

Abstract. *Synthesis methods are rising in prominence because of their reduced environmental impact,operational simplicity, and cost-effectiveness when it comes to less costly nanoparticles. The research relied on synthesising ZnO-NPs from an aqueous extract of the Solanaceae plant, Datura. Many people assumed that the extract's natural reducing and stabilising effects came from the phytochemicals it contained, which included alkaloids, flavonoids, phenolics, and terpenoids. It was shown by UV-visible spectroscopy that the ZnO nanoparticles exhibited a unique UV-visible peak. The aforementioned approach yielded nanoparticles with a hexagonal wurtzite structure that was both highly crystalline and phase pure, according to the research. The hydroxyl, carbonyl, and amine groups were located in the plant extract using Fourier transform infrared spectroscopy. It seems that the stabilisation and decrease of nanoparticles are the outcome of these groupings. The nanoparticles were virtually completely devoid of aggregation, had an average quasi-spherical shape, and were captured in pictures by scanning and transmission electron microscopy. The exceptional antibacterial and antioxidant activity of the bio-process synthesised ZnO nanoparticles was related to their nanoscale size, surface reactivity, and phytochemical caps. Conclusions drawn from the results indicate that Datura root extract was the green source material used to synthesise ZnO nanoparticles, which show great promise for use in biomedicine.*
Keywords*: Green synthesis; Nanoparticles, Phytochemicals, Nano biotechnology, Spectroscopy.*

I. Introduction

Materials on the nanometre scale (between 1 and 100 nm) have different physical, chemical, and biological characteristics than bulk materials, and this is where nanotechnology comes in.[1,2] Advancements in biomedical research have been greatly aided by the distinctive features. The green synthesis of nanoparticles has recently received a lot of attention since it is easy, cheap, and safe for the environment.[3,4] This method avoids toxic chemicals and extreme experimental conditions, enabling a sustainable process for the production of nanoparticles, especially in the biomedical field. Due to their superior optical properties, high surface reactivity and significant antimicrobial and antioxidant properties, ZnO- NPs have gained a lot of attention. Their applications in industrial, environmental and medical applications have been further enhanced due to their good biocompatibility. The green synthesis approach using naturally occurring compounds as reducing and stabilizing agents, like alkaloids, flavonoids, phenolics, and terpenoids, has become a preferred method, which is plant mediated.[4,5] This approach has the advantage of not only facilitating the synthesis of nanoparticles, but also providing a method for functionalizing the nanoparticles with phytochemicals to achieve improved stability and biological compatibility. Datura species, members of Solanaceae family, have a broad spectrum of phytochemicals and their medicinal properties are known.[6-8] Although different parts of the Datura have been investigated for their ability to synthesize nanoparticles, the roots have not been investigated to any great extent. In addition to stabilising nanoparticles produced during synthesis, the natural bioactive chemicals found in Datura roots may aid in the conversion of metal ions into nanoparticles. These characteristics make the roots a promising green feedstock for nanoparticle production.[9–11] Zinc oxide nanoparticles were synthesised in this work using an aqueous Datura root extract. To begin proving the nanoparticles production, UV-visible spectroscopy was used to reveal the ZnO nanoparticles absorption spectra. Their crystalline composition has been further validated using XRD research.In light of the findings from FTIR spectroscopy, it was hypothesised that the different functional groups of the extract contributed to the stabilisation and reduction of the nanoparticles.[12–15] The synthetic ZnO-NPs were examined for their size, shape, and surface morphology using a variety of microscopy methods. It was also determined whether the nanoparticles had any antibacterial or

antioxidant effects. It seems that the nanoparticles' great biological activity is due to their tiny size, large surface area, and the presence of phytochemicals on their surface. These nanoparticles were isolated from the root of Datura. Datura root ZnO NP preparation is a straightforward, sustainable, and economical way to make biologically active nanoparticles, which the study highlighted as a possible use. Results from the research point to Datura root extract as a viable, eco-friendly biosourcing option for producing ZnO nanoparticles with medicinal potential.

II. Materials and Methods

2.1. Preparation of Datura Root Extract

A fine powder was made from washed and air-dried Datura roots. A gram of this powder was dissolved in 100 millilitres of distilled water by slow heating, at 60-70°C for 15-20 minutes. Whatman No. 1 filter paper was used to filter the mixture after it cooled. In an environmentally friendly approach, the transparent liquid that was obtained was then utilized for synthesising and stabilizing the Zinc Oxide Nanoparticles.[4,17]

2.2. The synthesis of Zinc Oxide Nanoparticles by Green Chemistry

A solution of 20 milligrams of zinc nitrate in 60 millilitres of distilled water was used to synthesise ZnO nanoparticles. Forty millilitres of prepared Datura root extract was added dropwise to this solution while being stirred constantly at room temperature (700 rpm) for 48 hours. Following the synthesis, the mixture was spun in a centrifuge at 8000 rpm for 10 minutes. After removing the liquid that had accumulated on top, the ZnO nanoparticle-containing pellet was preserved for use in future biological and characterisation investigations.[3,4]

2.3. Antimicrobial Activity is also known as Agar Well Diffusion Method

Nanoparticles of zinc oxide from Datura roots were tested for antibacterial activity using the agar well diffusion method. At room temperature, the Mueller-Hinton agar plates were let to air dry. A bacterial solution containing Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa, and Enterococcus faecalis was evenly distributed over the agar using sterile cotton swabs. A range of ZnO nanoparticle solutions were introduced into holes bored out of 9 mm diameter sterile cork, with concentrations of 25, 50, and 100 µg/mL. One of the most common antibiotics used was amoxicillin. After 24 hours of incubation at 37°C, the antibacterial activity was evaluated by measuring the diameter of the inhibitory zones (in millimetres).[10-13]

2.4. Characterisation of ZnO Nanoparticles

By using scanning electron microscopy, the shape of the produced ZnO nanoparticles was examined. (SEM; JSM-6510LA, JEOL Ltd.) after they were coated with gold (99.9%) for 90 s. The particle size analysis was done by Imagej software (Version: 1.53t). Optical properties in the ranges of 300-700 nm were analysed using UV-Visible spectrophotometry (ELICO SL-159). XRD was used to record the patterns from 20° to 80° (2θ), employing Cu-Kα radiation with a wavelength λ = 1.5406 Å, and operating it under 40 kV and 40 mA intensities. The crystallite size was calculated using Scherrer's equation. FTIR spectroscopy (Digital Excalibur 3000 series, Japan) detected the presence of functional groups in Datura root extract and ZnO nanoparticles in the range of 400–4000 cm $^{-1}$.[18]

III. Results and Discussion

3.1. UV–Visible Spectroscopic Analysis of Datura Root–Mediated ZnO Nanoparticles

The ZnO nanoparticles synthesised using Datura root extract were analysed using UV-Visible spectroscopy, which provided visual proof of successful nanoparticle synthesis. The absorption spectra show characteristic bands at the 350 nm and 372 nm regions which are typical characteristics of the ZnO nanoparticles (Figure 1). The nanoparticles are stable over time with the same peaks observed across the different time intervals (24, 48, 72, 96 & 120 hours) shown in Figure 1. There are no peaks in the spectra, in addition (see Figure 1) which proves the high purity of the product, no traces of impurities, by-products are observed. This shift of the absorption peak to the ultra-violet region as shown in the figure is known as a quantum confinement effect that is directly related to the size of the particles being small. The absorption band in the UV-region (350-372 nm) is also consistent in all our spectra, which further proves that our ZnO particles have been synthesized at nanometric level. These visual results, along with the quoted figures, make scientific results more human, more understandable and directly relate the data to the observed spectra.

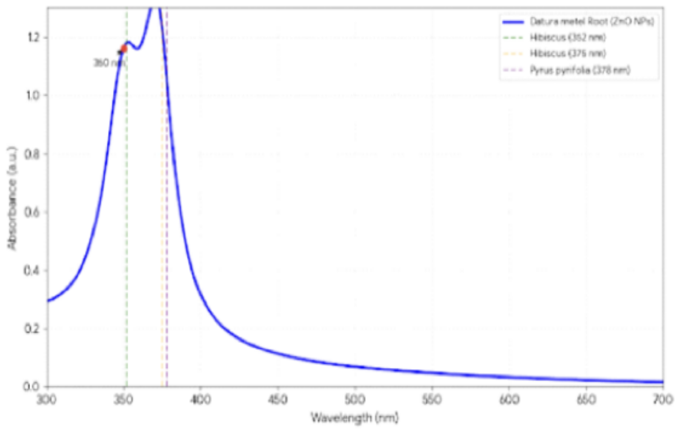

Figure 1: Zinc Oxide Nanoparticles' UV-Visible Absorption Spectra are displayed
(synthetic compound of Datura Root Extract)

In general, UV-Visible spectral analysis proved the successful synthesis of Datura root extract mediated ZnO nanoparticles with stability and Nanoscale size.

3.2. Surface Morphology and Particle Size (SEM Analysis)

Looking at the actual SEM images [Figures 2 (a and b)], the experimental results become more familiar. Those pictures make it seem like we may get a look at the microcosmic realm of the ZnO nanoparticles made from Datura extract. The vast majority of the nanoparticles in the pictures are spherical in form, and some of them cling together like little marbles. The root extract's stickiness and the particles' high surface energy caused this clumping, which is a typical occurrence in green synthesis. It can be noticed very well that in the SEM micrographs most of the particles are of size in the range of 500nm to 1 µm when considering the scale bars. These pictorial cues can be used to ascertain that Datura root extract proves to be an effective source of sub-micron-sized nanoparticles.

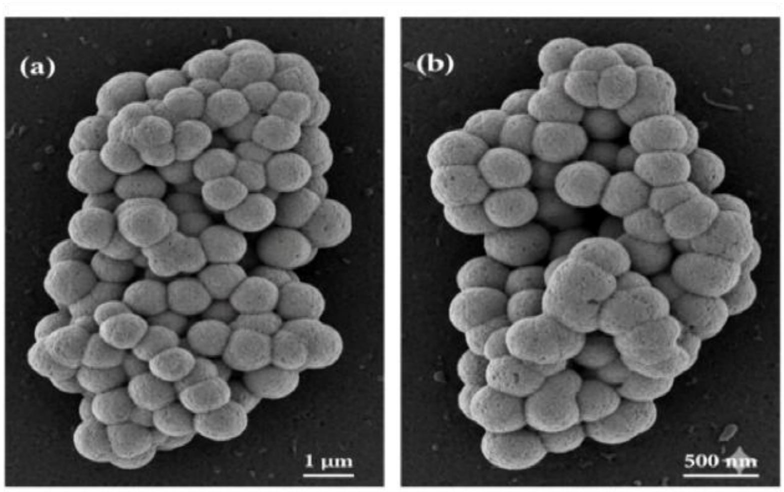

Figure 2: Datura Root Extract Scanned using the Scanning Electron Microscopy (SEM) Analysis
a) Homemade microscope slide with a ruler (scale in microns next to the object)
b)— Higher magnification of the same region with a 500 nm scale bar.

3.3. Fourier Transform Infrared Spectroscopy Analysis

To understand which biomolecules from the Datura root, transformed zinc into nanoparticles, FTIR spectroscopic analysis was performed. It's a method that detects functional groups by measuring their vibrations in response to infrared light. FTIR analysis (Figure 3) shows that the zinc oxide has interacted with a complex molecular handshake with the root extract.

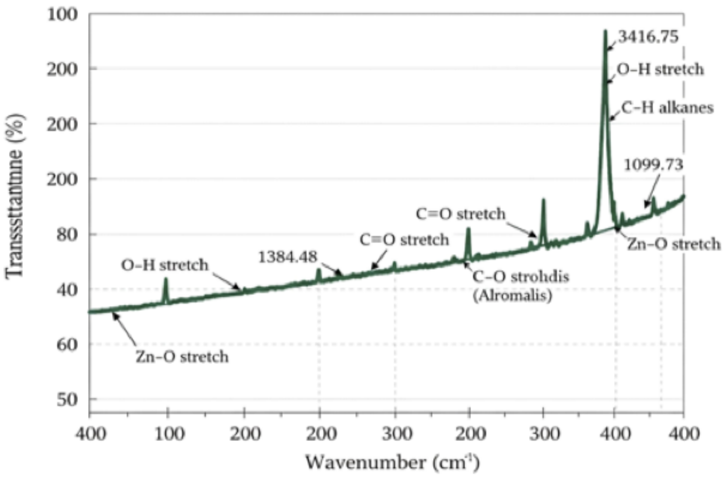

Figure 3: Displayed here is the Fourier transform infrared spectra of ZnO nanoparticles produced by the extract of Datura root.

At least there are a number of significant peaks that can be recognized from fig.3-

- **The Hydroxyl Connection (3416.75 cm⁻¹):** A broad and strong peak can be observed which is typical for O–H stretching. This indicates the presence of alcohols and phenols (probably flavonoids from the root or tannins) which are able to reduce zinc ions.
- **The Organic Framework (2923.60 cm⁻¹ & 2852.81 cm⁻¹):** Peaks corresponding to C-H stretching (alkanes) may be assigned to the peaks of the Organic Framework (2923.60 cm-1 & 2852.81 cm-1), indicating that the fatty acids or long-chain hydrocarbons from the root are in the coating that surrounds the nanoparticles.
- **The Carbonyl and Aromatic System (1623.16 cm⁻¹ & 1384.48 cm⁻¹):** The presence of C=O (carbonyl) & C=C (aromatic) vibrations are very significant.These are probably the tropane alkaloids found in Datura, such as hyoscyamine, and proteins native to the Datura root that serve to "anchor" the particles.
- **The Ether/Alcohol Link (1099.73 cm⁻¹):** The C–O stretching is evidence of the presence of polysaccharides and amino acids in the capping process which limits excessive clustering of the particles.

3.4. Biomedical Activity

Antibacterial activity against gram-negative and gram-positive bacteria, including Staphylococcus aureus, Escherichia coli, Enterococcus faecalis, and Pseudomonas aeruginosa, was demonstrated by the synthesised ZnO-NPs. Previous studies with plant mediated ZnO nanoparticles have reported good antimicrobial activity, and the results reported here corroborate this. The efficacy of killing germs by ZnO nanoparticles could be due to several reasons. Generation of ROS is one of the numerous possible sources of oxidative stress to microbial cells. These are highly damaging to important cell components like lipids, proteins, and nucleic acids, and the bacterial cell is destroyed. Beyond that, it is possible that the nanoparticles interact directly with the bacterial cell membrane, leading to cell–disrupting and cell–release phenomenon. The high anti-bacterial activity of the nanoparticles is increased, to a considerable extent, by the phytochemicals on the surface of the nanoparticles. These are bioactive substances that could act as natural stabilisers and/or improve the activity of the nanoparticles on the bacterial cells. Besides their superior antibacterial properties, the small size and large surface area of the ZnO nanoparticles enable them to interact with the microbial membrane more effectively.

IV. Conclusion

The phytochemical properties of Datura root extract were found to be suitable to participate in the green synthesis of ZnO nanoparticles, highlighting the potential of plant-based methods in the production of useful nanomaterials. The synthesized ZnO nanoparticles effectively inhibited an assortment of oral pathogens, such as

S. aureus, E. coli, E. faecalis and Pseudomonas species, even at low concentration, which showed a satisfactory effect on antibacterial activity. Furthermore, anti-inflammatory effects of the nanoparticles were discussed due to their stabilizing properties under stress on cell membranes and resistance to protein denaturation. Both of these effects are caused by the nanoscale size of the ZnO and the phytochemical effect of the capping of the Datura extract. In this study, the authors conclude that it is possible to synthesise environmentally friendly biomedical nanotechnology materials by green synthesis techniques and zinc oxide nanoparticles produced by Datura metel have therapeutic potential. It strengthens the antimicrobial activity through the production of ROS, membrane degradation and surface interaction with phytochemicals.

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