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Livistona chinensis-Mediated Zinc Nanoparticle Synthesis: Comprehensive Analysis through UV, IR, XRD, SEM, and TEM Techniques

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Abstract

This study presents a comparative analysis of zinc nanoparticles synthesized using Livistona chinensis leaf extract as a green and sustainable approach. The nanoparticles were synthesized through the reduction of zinc nitrate, and their properties were thoroughly characterized using various spectroscopic and microscopic techniques. UV spectroscopy identified distinct absorption peaks, confirming the successful synthesis of zinc nanoparticles. Infrared spectroscopy (IR) offered insights into the functional groups engaged in the reduction and stabilization process, while X-ray diffraction (XRD) validated the crystalline nature of the nanoparticles. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) provided a detailed examination of the morphological and structural attributes, showcasing unique features and size distribution of the zinc nanoparticles. Dynamic light scattering (DLS) was employed for studying the hydrodynamic size and stability of the nanoparticles in solution. The comparative analysis through various spectroscopic and microscopic techniques provides comprehensive insights into the synthesized zinc nanoparticles. This research contributes to the growing field of green synthesis methods, highlighting Livistona chinensis leaf extract as a promising and sustainable precursor. The detailed characterization is essential for understanding the potential applications of these zinc nanoparticles in various fields, including biomedical and nanotechnology.

Keywords: Livistona chinensis, Zinc nanoparticles, Green synthesis, Characterization

Nanotechnology applications

Introduction:

Livistona chinensis, commonly known as the Chinese fan palm, has emerged as a promising candidate for the environmentally friendly production of zinc nanoparticles. This study investigates the comprehensive analysis of zinc nanoparticles synthesized using Livistona chinensis leaf extract, employing a sustainable and eco-conscious approach [1,2]. Nanoparticles, particularly those of zinc, exhibit distinct properties with versatile applications in fields such as medicine and catalysis [3]. The utilization of Livistona chinensis leaf extract as both a reducing and stabilizing agent in the synthesis process aligns with the principles of green synthesis, effectively addressing environmental concerns associated with traditional chemical methods [4]. The bioactive compounds present in the leaf extract serve not only as efficient reducing agents but also impart unique characteristics to the resulting zinc nanoparticles [5,6].

Confirmation of the successful synthesis of zinc nanoparticles is a crucial aspect of this study, achieved through UV spectroscopy. The clear identification of absorption peaks in UV spectroscopy serves as undeniable evidence of nanoparticle formation. Additionally, infrared spectroscopy (IR) is employed to elucidate the functional groups involved in the reduction and stabilization processes during synthesis, providing essential insights into the potential applications of the nanoparticles in various scientific and technological domains. The morphological and structural features of the nanoparticles are meticulously examined using scanning electron microscopy (SEM) and transmission electron microscopy (TEM). This parameter is vital for evaluating the potential applications of the nanoparticles across different scientific and technological domains [7-14].

Contributing to the evolving field of green synthesis methods, this research underscores the significance of Livistona chinensis leaf extract as a promising and sustainable precursor for nanoparticle synthesis. The detailed characterization presented in this study establishes a foundation for comprehending the unique properties of Livistona chinensis-mediated zinc nanoparticles and their potential applications.

2. Experimental Details

Zinc nitrate (ZnNO3) and sodium borohydride (NaBH4) were employed in the fabrication of ZnNPs. The glassware utilized in the experiment underwent thorough cleansing, rinsing with distilled water, and drying in a hot air oven. To ensure sterility, Petri dishes designated for antibacterial studies underwent autoclaving before use. Fresh leaves of P. biglandulosa were gathered from GVISH, Amravati, and authenticated by the Plant taxonomist at the Department of Botany. All requisite chemicals, sourced from Sigma-Aldrich, were used in the experiment.

The collected leaves were washed with purified water and then dried in a hot air oven at 50°C overnight. Subsequently, the dried leaves were finely crushed and ground using a mixer grinder. The resulting material was mixed with sterilized distilled water and filtered through a Whatman No.1 filter paper to obtain the leaf extract. ZnNPs with a concentration of 80 mM were synthesized by dissolving 0.470g of Zinc nitrate in 30 ml of an aqueous solution containing the previously prepared P. biglandulosa leaf extract. The reaction mixture underwent continuous stirring until a noticeable color change occurred, transitioning from yellowish-brown to greyish-brown.

Microwave irradiation was applied to the reaction mixture for approximately 120 seconds, resulting in a dark brown color of the extract. The Tyndall effect, indicative of the scattering of light, was observed in the presence of light [14-18].

3. Results and Discussion

Characterization:

The characterization of the synthesized Zinc nanoparticles (ZnNPs) encompassed a thorough examination of their morphological, physical, and chemical properties, employing a variety of standard techniques. The following methods were employed through established procedures:

1. **Scanning Electron Microscopy (SEM):**

SEM was utilized to investigate the surface morphology and size distribution of the synthesized ZnNPs. The images obtained provided insights into the physical structure and topography at the nanoscale.

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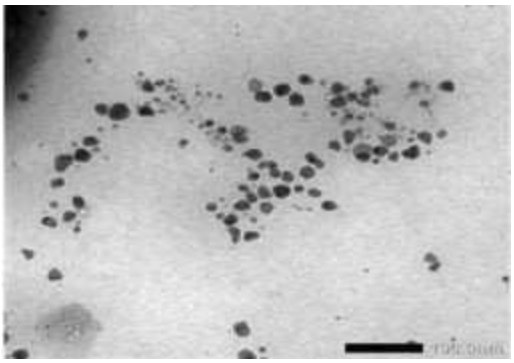
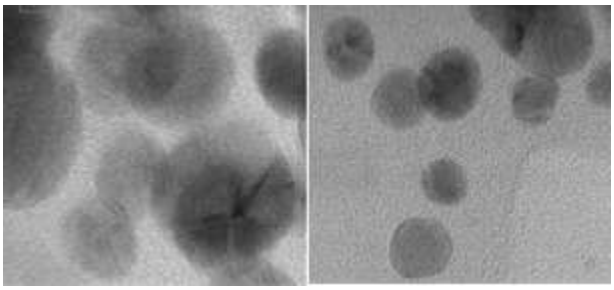


The investigation into the surface morphology and elemental composition of the synthesized Zinc nanoparticles (ZnNPs) employed SEM (Scanning Electron Microscopy) from Hitachi (S-4200; Tokyo, Japan) and EDX (Energy-Dispersive X-ray Spectroscopy) by EDAX Inc. (Mahwah, NJ, USA). The process commenced with the meticulous powdering of samples using a mortar and pestle, followed by an even dispersion of a small quantity over carbon tape affixed to the sample holder. Subsequently, the prepared sample holder underwent a 120-second sputter coating process in an ion coater machine to apply a thin, conductive layer.

Placed within the SEM machine under vacuum conditions, the coated sample holder allowed the examination of ZnNPs' surface morphology by focusing the lens. Simultaneously, the elemental composition was scrutinized using the EDX machine (EDS; EDAX Inc.) integrated with the SEM apparatus. The resulting images and data were diligently recorded using a computer system connected to the SEM machine, contributing to a comprehensive understanding of the synthesized ZnNPs.

2. Transmission Electron Microscopy (TEM):

TEM analysis was conducted to achieve higher resolution and detailed visualization of the ZnNPs. This technique allowed for a closer examination of the particle size, shape, and distribution. TEM image show zinc na



TEM images revealed that the ZnNPs exhibited a predominantly spherical shape with monodispersed distribution and an average particle size of 15 nm. At low resolution, the nanoparticles were well-separated, displaying uniform interparticle separation (Fig.). The TEM images (Fig. 3a and b) indicated that the surface of the Zinc nanoparticles was coated with an organic layer.

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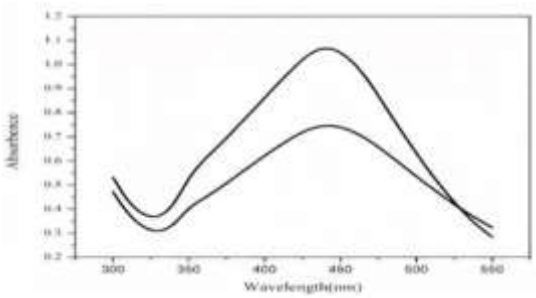
3. **UV-Visible Spectroscopy**:

UV-Visible spectroscopy was employed to confirm the formation of ZnNPs by identifying characteristic absorption peaks. The spectra obtained assisted in determining the optical properties and stability of the synthesized nanoparticles.

UV-VIS was utilized to study the optical properties of the synthesized Z nNPs. FT-IR analysis was performed to examine the chemical composition and functional groups present in the synthesized ZnNPs. SEM was employed to investigate the morphological features and surface characteristics of the ZnNPs. EDX analysis provided insights into the elemental composition of the synthesized ZnNPs. XRD analysis was carried out to determine the crystallographic structure and phase purity of the synthesized ZnNPs. Each of these techniques played a crucial role in revealing specific aspects of the ZnNPs, contributing to a comprehensive understanding of their properties.

To investigate the impact of three distinct lighting conditions on the biosynthesis of Zinc nanoparticles (ZnNPs), absorption spectra of the solutions were acquired using a UV-VIS spectrophotometer (Multiskan GO; Thermo Scientific, Waltham, MA, USA). The spectral data were collected with a 2-mm resolution over a wavelength range of 300 to 700 nm for a duration of 24 hours.

Three separate sets of samples were collected and subjected to analysis, with absorption measurements taken at hourly intervals. The wavelengths were scanned between 300 and 700 nm, with a 2-nm difference at each interval. The absorption spectral values and the observed colors of the solutions were meticulously documented at each time point. This rigorous monitoring process allowed for a detailed examination of the temporal evolution of absorption characteristics under different lighting conditions.



4. **Fourier Transform Infrared Spectroscopy (FTIR):**

FTIR analysis was carried out to identify the functional groups present on the surface of the ZnNPs. This information is crucial for understanding the chemical composition and potential interactions with biological or chemical entities.

The FT-IR spectra of the synthesized Zinc nanoparticles (ZnNPs), produced under both laboratory lighting and sunlight conditions, as well as the Parkia biglandulosa (PB) extract, were acquired using an FT-IR spectrophotometer (Spectrum Two TM FT-IR Spectrometer; PerkinElmer, Waltham, MA, USA). The spectra were meticulously recorded across the wavelength range of 400 to 4000 cm−1.

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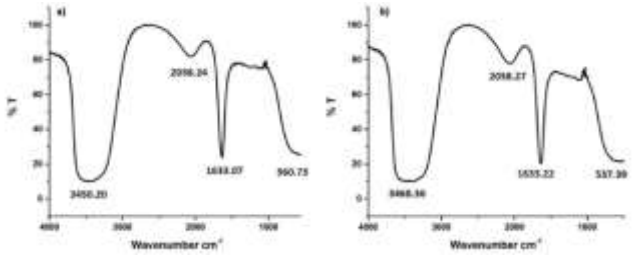
To conduct the analysis, approximately 5 µL of each sample was applied to the sample collector point of the instrument. The spectrophotometer was then activated, capturing readings through specialized software integrated with the connected computer system. The obtained data were systematically compiled as values in an MS Excel sheet, facilitating organized storage and analysis. Subsequently, a corresponding graph was generated for visual interpretation and detailed analysis of the FT-IR spectra. This method allowed for a comprehensive exploration of the molecular characteristics and functional groups present in the synthesized ZnNPs under different lighting conditions, as well as in the PB extract.



4.C**onclusion**

In this study, Zinc nanoparticles were biologically synthesized utilizing the leaf extract of P. biglandulosa and comprehensively characterized through UV–Visible spectroscopy,SEM TEM, and IR analyses. The synthesized Zinc nanoparticles exhibited remarkable stability for approximately 2 months without any agglomeration.SEM, TEM results revealed that the Zinc nanoparticles predominantly exhibited a spherical shape with an average particle size of 15 nm. Additionally, These findings suggest that the developed biosynthesized Zinc nanoparticles hold potential for diverse medical and pharmaceutical applications.

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