

Green Synthesis of SiO₂ Nanoparticles from *Musa Acuminata* Rhizome: Characterization and Biomedical Applications

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ABSTRACT

The formulation of effective wound healing gels as an alternative to the production of synthetic drugs. In this research, SiO₂ nanoparticles were synthesized using the rhizome extract of *Musa acuminata* via green synthesis. The physicochemical and morphological characterization affirmed the effective synthesis of SiO₂ NPs. The in vitro cell migration and cell viability assays revealed the biocompatibility of the SiO₂ NPs. These results demonstrate improved wound healing efficacy and an eco-friendly nature of the SiO₂ NPs, contributing to a promising silica-based nanomaterial for biomedical applications.

Keywords: *Musa acuminata*, Green synthesis, SiO₂ nanoparticles, Biomedical applications.

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INTRODUCTION

Nanoparticles come into existence through various synthesis methods: physical, chemical, and biological. The biological route relies on plant biomass, as well as bacteria, fungi, and algae. The banana plant (*Musa acuminata*) belongs to the Musaceae family. Across tropical and subtropical regions, bananas are a staple food for millions and stand as one of the top fruits exported globally¹. In recent developments, various nanoparticles have been created using different parts of *M. acuminata*, like colla bracts, flowers, leaves, and rhizomes. The flower has properties that fight bacteria and may also help in cancer treatment². Zinc oxide NPs, Copper oxide NPs synthesized using *M. acuminata* extract for antibacterial purposes^{3,4}. Iron oxide NPs from *M. acuminata* to eliminate yellow dye⁵. Silicon and oxygen are the abundant elements on Earth. Silicon is found in both amorphous and crystalline form. Silica has an important role in industrial applications for manufacturing concrete bricks, and glass. To synthesize SiO₂ NPs, sol-gel method was employed. SiO₂ NPs were synthesized using Tetraethyl orthosilicate (TEOS) in ethanol and plant extract. SiO₂ NPs have significant contribution in agriculture since they positively impact plant growth and help minimize environmental stress, provide effective solutions for agricultural challenges, including weeds, diseases, pest problems, abiotic stresses, and crop yield reduction through precise delivery methods⁶. This research study focuses on the synthesis, characterization, and analysis of wound healing capabilities and cytotoxic effects of SiO₂ NPs synthesized using Rhizome extract from *M. acuminata*.

MATERIALS AND METHODS

Collection of Rhizome

The rhizome of *Musa acuminata* was collected from a local farm in Trissur, Kerala, India. Tetraethyl orthosilicate (TEOS), ethanol, and other required chemicals were procured from Sigma Aldrich, Mumbai.

Extract preparation

M. acuminata rhizome was taken and washed with tap water. A fresh extract was obtained by grinding in a mortar and pestle, then filtering through muslin cloth. The filtrate was stored at 4 °C for further analysis.

Synthesis of SiO₂ nanoparticles

10 mL aqueous extract of rhizome was added to the mixture containing 5 mL TEOS, 3 mL distilled water, 7 mL ethanol, and placed on a magnetic stirrer at 80 °C for 30 min. The resulting pellet was recovered by rinsing with distilled water and ethanol thrice. Then it was dried in a hot air oven and the powder was collected and stored in a sterile container.

Characterization of SiO₂ NPs

The optical property of SiO₂ NPs was analyzed by using a UV-visible spectrophotometer (Shimadzu/206-26300-48). The crystalline nature of the SiO₂ NPs was determined via XRD analysis (X'Pert Pro PANalytical). FTIR analysis (SHIMADZU Miracle 10) determined the chemical composition. Size and morphology were observed using a FESEM, and EDX analysis determined the atomic weight percentage of the elements (TESCAN-MIRA3 XMU). The

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Thermo Gravimetric Analyzer (EXSTAR/6300) was used to analyze the thermal stability.

Biological Assessment of SiO₂ NPs

Cell proliferation and Cytotoxicity were assessed using L929 fibroblast cells via the Scratch and MTT assays.

In-vivo Wound Healing Assay

For the cell proliferation assay, the cell cultures were inoculated into a cell culture plate containing FBS (10%) enhanced DMEM. 90% of confluence as a monolayer was achieved after 24h incubation. A minor incision was done in the center of the monolayer using a sterile blade. PBS was used to wash the monolayer to eliminate remains. 100 µg/mL of SiO₂ NPs was applied on the incision as a treatment, positive control Basic Fibroblast Growth Factor (bFGF) of 20 µg/mL was used as a positive control, and Cytochalasin D was used as an inhibitory control. The treated cell cultures were incubated in 5% CO₂ at 37 °C and cell proliferation rate was recorded at 0, 24, 48, and 72 h to estimate the wound-healing efficiency of SiO₂ nanoparticles.

In-vivo Cytotoxicity Assay

In the cytotoxicity assay, fibrocyte cells were revived from a cell culture with passage numbers below 12 was added

to DMEM containing 10 % FBS. Different concentrations of synthesized SiO₂ NPs (20 -100 µg/mL) were inoculated into a 96-well plate were sustained at 37 °C and 5 % CO₂ environmental circumstances for the incubation. Triton X-100 (100 µg/mL) and sterile water were used as positive and negative controls, respectively. Post 24 h of incubation at 37 °C. The Cytotoxicity assay was performed using Diphenyltetrazolium bromide (MTT). Formazan crystals accumulation confirmed the breakdown of live cells by MTT. Optical density of the formazan crystals was estimated at 570 nm using a multi-well ELISA plate reader.

RESULTS AND DISCUSSION

The UV-visible spectrum showed a prominent peak at 280 nm for the rhizome extract and a slight peak at 160 nm for SiO₂ NPs (Fig 1a)⁷. The FTIR spectrum of the rhizome extract in Fig 1b denoted functional groups such as alcohol, alkyne, phenol, amine, and metal oxides⁸. The FTIR spectrum of SiO₂ NPs in Fig 1c depicted functional groups like alcohol, alkene, fluoro compound, alkyl halide, and metal oxides⁹. The XRD spectrum in Fig 1d explained the amorphous nature of SiO₂ nanoparticles with a particle size of 83.9 nm was calculated using Debye-Scherrer derivation¹⁰.

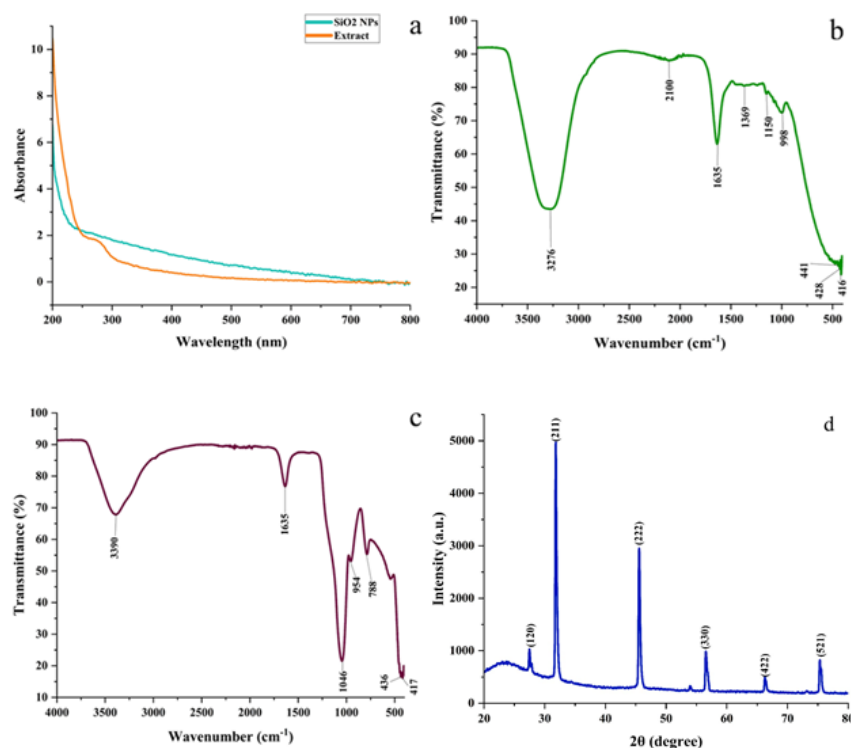


Fig. 1. Characterization of Rhizome extract and SiO₂ NPs. (a) UV spectrum, (b) FTIR spectra of rhizome extract, (c) FTIR spectra of SiO₂ NPs, (d) XRD spectrum

FESEM micrographs in Fig. 2a and b depicted the spherical shape, and the EDX spectrum in Fig 2c showed the presence of Si (40.65 %), O (50.01 %), and C (9.34 %) through the elemental composition¹¹. In Fig 2d, a total

weight loss of 32.4 % due to the evaporation of water molecules and desiccation of carbon residues was illustrated by the thermogravimetric analysis¹².

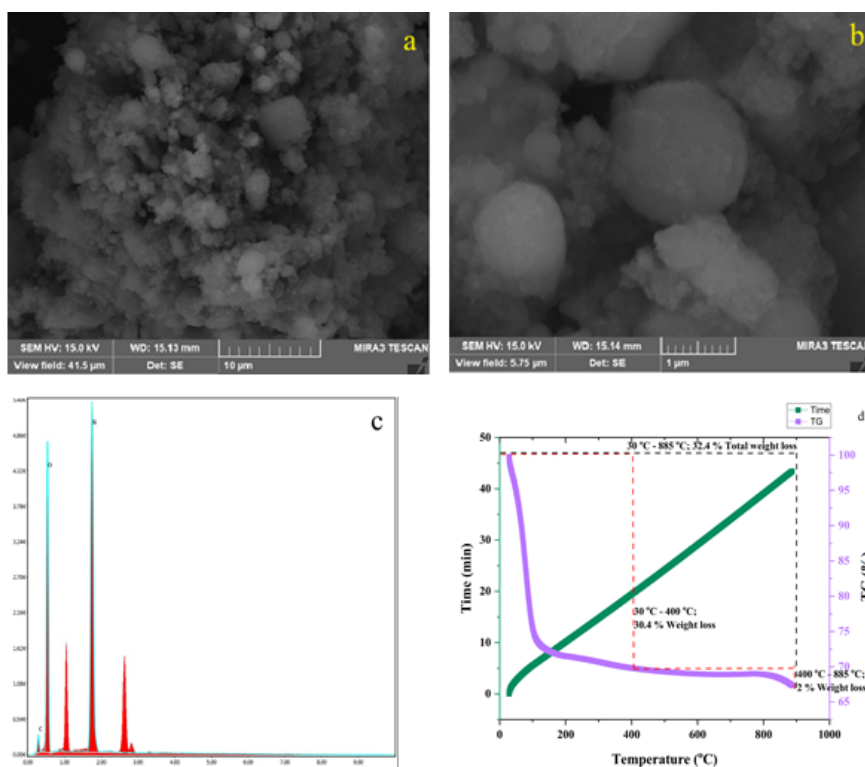


Fig. 2. Characterization of SiO₂ NPs. (a and b) FESEM micrographs (c) EDX spectra, (d) TGA

The cell proliferation potential was determined using the L929 cell lines via scratch assay. Fig 3a showed wound closure of 34% after 24 h of incubation, 56 % after 48 h, and 78 % of 72 h, due to the cell-signaling routes to promote cell proliferation and cell migration¹³. The cell viability of nanoparticles was disclosed using L929 cell lines via MTT assay. Fig 3b displayed the highest cell

viability of 71.81 % at 20 μg/mL and the least cell viability of 54.23 % at 100 μg/mL. Increased concentrations of SiO₂ nanoparticles formed an increased level of ROS in cells, thereby inducing oxidative stress, disrupting the cells, and causing damage to cellular organelles and membranes¹⁴. The p-value less than 0.05 indicated the relevance of the assays.

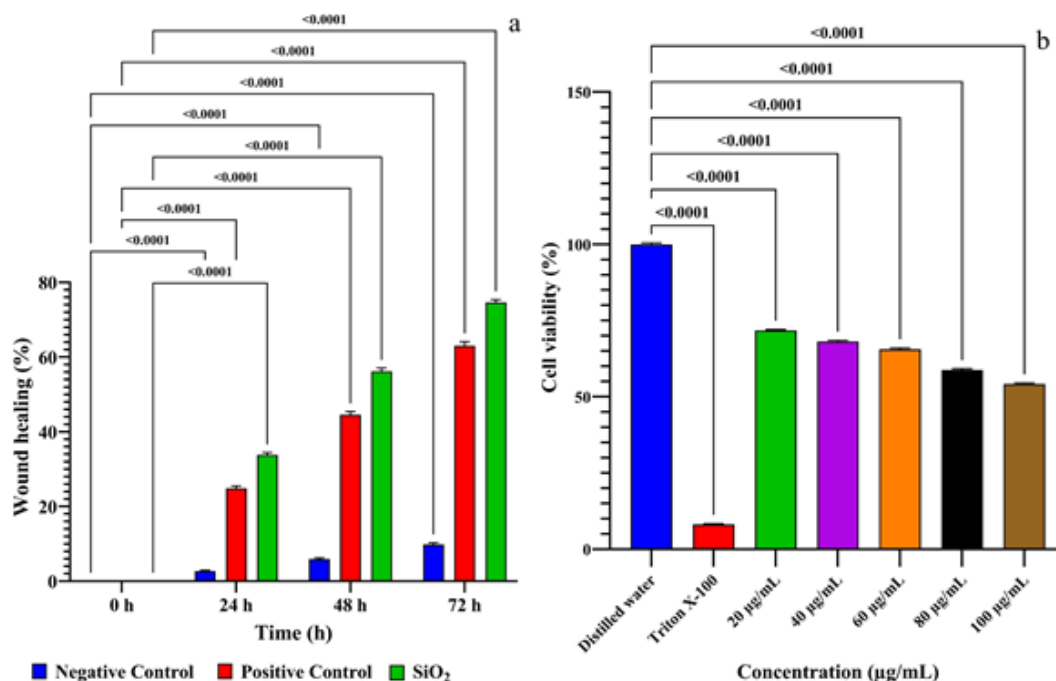


Fig. 3. Biological activity (a) Cell proliferation (b) Cell viability

4. CONCLUSION

SiO₂ nanoparticles were green-synthesized using the rhizome extract of *Musa acuminata*. The structural and physicochemical characterization confirmed the synthesis of SiO₂ nanoparticles. The cell proliferation of 78 % demonstrated the wound healing efficacy, and the cell viability of 54.23 % at 100 µg/mL determined the biocompatibility of SiO₂ nanoparticles. These results suggest that SiO₂ nanoparticles might be useful in the formulation of effective and compact wound healing gels, minimizing the need for commercial synthetic gels.

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* Author's Contributions

Mrs. Vinitha Ebziba C: Investigation and Writing- Original draft preparation

Mr. Hari Haran K: Data Curation

Mr. Joaval Antony Martin: Data Curation

Dr. Rajiv Periakaruppan: Review and Editing

Dr. Senthil Kumar J: Conceptualization, Supervision, Funding acquisition, and Project administration

***Ethics approval, Consent to participate, Consent for publication, Availability of data and materials, Acknowledgements, Authors' information (optional), Please include the sub-sections below of compliance with Ethical Standards section, Disclosure of potential conflicts of interest, Research involving Human Participants and/or Animals, Informed consent – Not applicable**

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