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# Synthesis of Silicon Dioxide Nanoparticle as Biologically Derived Therapeutic Agent using *Streptomyces hygroscopius* and Leafy Extracts of *Cynodon dactylon*

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## ABSTRACT

Nanotechnology involves the design, production and application of structures, devices and systems by controlling the shape and size at the nanometre scale. It is currently considered as potential technology which brings the many benefits to diverse areas such as drug development, water decontamination, information, production of stronger and lighter material etc. Si NPs are most extensively used in the biomedical field due to their higher stability in pH, temperature and other chemicals which leads to superior biocompatibility, cost-effective and eco-friendly. In the present study we used *Streptomyces hygroscopius* (microbial approach) and *C. dactylon* leaf extract (green approach) as comparative for the synthesis of silicon dioxide nanoparticles. The actinobacterial strain was identified as *Streptomyces hygroscopius* (RGS17) with accession number MZ031397. The biosynthesized $SiO_2$ nanoparticles were confirmed through UV-Vis spectroscopy with characteristic absorbance at 320 nm and XRD analysis indicated their amorphous nature. FTIR analysis revealed the presence of various functional groups contributing to the reduction, capping and stabilization of the nanoparticles. SEM analysis confirmed the spherical morphology of both Sh-SiNPs and *C. dactylon*-mediated SiNPs. The antibacterial activity tests showed that Sh-SiNPs had stronger inhibitory effects against *Escherichia coli* and *Bacillus cereus*, suggesting encouraging medicinal potential. the efficiency of actinobacterium-mediated silica nanoparticle manufacturing as a bioactive and sustainable method for antibacterial and antioxidant applications.

## Introduction

Nanotechnology is currently a rapidly advancing, transformative field, predominantly in its first and second generations of development, which involves manipulating matter at the 1 to 100 nanometer scale to create enhanced materials and active in varying applications. It is currently considered as potential technology which brings the many benefits to diverse areas such as drug development, water decontamination, information, production of stronger and lighter material etc. nanotechnology involves in the creation and manipulation of materials at nanometer scale either by scaling up from single group of atoms or reducing bulk materials (Benelmekhi *et al.,* 2021).

Silicon dioxide nanoparticles can be synthesized through various methods such as physical, chemical, biological and green synthesis. The physical and chemical method have some disadvantage such as high raw material cost, need high temperature to heat, shrinkage during the drying process and cause damage to the environment. Apart from these methods of synthesis, there are many methods to synthesize the silicon dioxide nanoparticles like green synthesis, microbial synthesis etc. Green and microbial synthesis of nanoparticles with the help of plants and microbes is an efficient, cost effective and does not cause any hazards to environment and biological. In the recent years, the most of the scientists are developing the both microbial and green synthesized nanoparticles such as zinc, silicon, silver, gold, indium, copper and calcium (Babu *et al.,* 2018; Yugandhar *et al.,* 2015). The synthesis process involves the usage of biological source which does not harm any naturally available resources which indeed also act as potential color reducers and hence indigenous microbial synthesis is preferred (Mohanraj *et al.,* 2022). Silicon dioxide has a core material may reduce the overall production cost of metal core shell nanostructure and used as substrate material for the immobilization of previous metals like titanium oxide, gold and nickel (Mohd *et al.,* 2019). Silica based nanoparticles have may valuable properties such as anti-oxidant, biocompatibility and anti-microbial. Si NPs are most extensively used in the biomedical field due to their higher stability in pH, temperature and other chemicals which leads to superior biocompatibility, cost-effective and eco-friendly (Periakaruppan *et al.,* 2025).

*Cynodon dactylon* is commonly known as Bermuda grass, also known as couch grass in Australia and New Zealand and found worldwide. It belongs to the family Poaceae and locally known as Arugampull in Tamil, Gerichagaddi in Telugu, Garike hullu in kannada languages (Babu *et al.,* 2018). Traditionally this herb is used to treat many diseases such as jaundice, skin infections, fever and rheumatic pains (Babu *et al.,* 2018; Bharati *et al.,* 2009; Dhanapal *et al.,* 2017). The plant has many biological activities that has been proved by scholars in recent years such as anti-oxidant, anti-diabetic, anti-inflammatory, anti-microbial and anti-arthritic (Jarald *et al.,* 2008; Garg *et al.,* 2011; Abdullah *et al.,* 2013; Saikouishk *et al.,* 2015). The *C. dactylon* were used in the green synthesis of gold nanoparticles due to its various biological activity. In previous reports it has proven that *C. dactylon* has lower the formation of kidneys stones, hyperglycemia, hyperlipidemia in rats due to its anti-oxidant and anti-diabetic property (Vinayagam *et al.,* 2021; Golshan *et al.,* 2017; Singh *et al.,* 2009; Karthi *et al.,* 2011).

Actinobacteria are Gram-positive, filamentous bacteria which is widely present in the natural ecosystems. Most of the researchers reveals that 80% of the antibiotics are actinobacteria originated especially with Streptomyces. In (Naresh *et al.,* 2021) the pigment producing actinobacteria is mediated for the synthesis of silver nanoparticles. Actinomycetes can produce a variety of secondary metabolites and those metabolites can have valuable properties such as anti-cancer, insecticides, herbicides etc. Streptomyces is a main source for many bioactive compounds and which lives in soil, produce volatile compounds like geosmin, which gives the good aroma during the rain (Lima *et al.,* 2017). *S. hygroscopius* is a filamentous-bacteria that form a complex network of branching hyphae and it belongs to the genus of Streptomyces (Tariq *et al.,* 2025). They are mostly found in decaying organic matter and plants roots. The (Ghareeb *et al.,* 2025) *Streptomyces vinaceusdrappus* marine actinobacteria used in the biosynthesis of selenium nanoparticles with potential therapeutic activity. In the present study we used *Streptomyces hygroscopius* (microbial approach) and *C. dactylon* leaf extract (green approach) as comparative for the synthesis of silicon dioxide nanoparticles and its biological activity.

## Materials and Methods

### Actinobacterial strain and identification

The actinobacterial strain RGS17 was collected from actinobacterial research laboratory, Department of

Microbiology, Periyar University, Salem, India. The strain was sub cultured in International Streptomyces Project 2 agar medium (ISP2) agar slants and used for the synthesis of silicon dioxide nanoparticles. Actinobacterial strain (RGS17) was cultivated in starch casein agar medium and incubated at 28ºC for 7 days for the mass production and the strain was molecularly characterized using 16s rRNA sequencing as published by (Elsilk *et al.,* 2022). The morphological structure of the potential strain was viewed by the scanning electron microscope (SEM).

## Synthesis of silicon dioxide nanoparticles using actinobacteria

The actinobacterial biomass was centrifuged at 6000 rpm for 10mins and washed three times in double distilled water. The cell debris was removed by centrifugation and the secondary metabolites of the actinobacterium were combined with sodium silicate as a precursor to create $SiO_2$ NPs (Garg *et al.,* 2022). The 100ml of actinobacterial supernatant was added with 1M sodium silicate in 250ml Erlenmeyer flask and stirred for 1hour at 400-500rpm. About 20ml of ethanol was added and stirred for 45mins for the precipitation formation. The contents were centrifuged (neuation ifuge UCO2R) at 5000rpm for 10mins to separate the mixture. The precipitation was washed 3 to 4 times with distilled water and dried at 80ºC in a hot air oven for 24 hours. The obtained powder was well ground with mortar and pestle and utilized for characterization and antimicrobial studies.

## Synthesis of silicon dioxide nanoparticles using *Cynodon dactylon* leaf extract

The healthy leaves of *C. dactylon* were collected from Periyar University Garden Salem, Tamil Nadu, India. The plant leaf was washed in water and dried under the shade for 10 days (Babu *et al.,* 2018). These dried leaves were well-ground using kitchen blender and sieved with 5 mm sieve plate for synthesis of SiNPs. About 20g of plant leaf powder was mixed with 500ml of 1M $HNO_3$ in 1000 ml Erlenmeyer flask and stirred for 24 hours. This mixture was filtered and washed with distilled water and dried in an oven at 100ºC for 12 hours. The evaporated turbid solution was stirred with 500 ml of 1M NaOH solution up to 24 hours in magnetic stirrer to reach the pH 12. The obtained reaction mixture was separated and titrated using 3M $HNO_3$ until the pH was attained up to 8.5-9.0. The contents were centrifuged at 5000 rpm for 10 minutes to separate mixtures. The precipitation was washed 3 to 4 times with distilled water and dried at 80ºC in a hot air oven for 24hours. The obtained powder was well ground with mortar and pestle and utilized for characterization and antimicrobial studies.

## Instrumental characterization of $SiO_2$ NPs

Ultraviolet visible spectrometric characterization of obtained nanoparticles was analyzed by using UV-vis spectrophotometer (Shimadzu UV-1800, Japan) the wavelength range 200 to 800nm. Fourier Transform Infrared (FT-IR) spectra (Shimadzu IR spirit, Japan) was analyzed using Kbr pellet method the wave number range from 400 to 4000 $cm^{-1}$. The nature of Si NPs was investigated by the XRD (Smart lab SE, Japan) analysis. The average size of Si NPs was calculated by the Scherrer formula (Periakaruppan *et al.,* 2024). Scanning electron Microscope (SEM) (Carl Zeiss Microscope EVO18, Germany) was used to view the structure of the synthesized silicon dioxide nanoparticles.

## $SiO_2$ NPs on anti-bacterial activity by agar well diffusion method

The agar well diffusion method was used to study the antibacterial activity of the synthesized silicon dioxide nanoparticles against the human pathogens. Antibacterial activity was evaluated against *E. coli*, *B. cereus, E. facelis and K. pneumoniae*. The silicon dioxide nanoparticles, antibiotics (chloramphenicol) were chosen for the as the control group for the study of antibacterial activity. Finally, the petri dishes were incubated for 24 h at 37 °C. In order to evaluate the antibacterial activity of the synthesized silicon dioxide nanoparticle, the diameter of the inhibition zone was measured and compared with the control groups (Babu *et al.,* 2018).

## Anti-oxidant activity of silicon dioxide nanoparticles

The potential anti-oxidant activity of silicon dioxide nanoparticles synthesized from actinobacterium and leaf extract of *C. dactylon* was investigated using DPPH assay. This method assesses the free radical scavenging activity by measuring the absorbance values of sample at various concentration. The single electron of DPPH is paired with hydrogen atom from anti-oxidant, the color changes from purple to yellow. In anti-oxidant analysis the aqueous extract of Sh mediated and *C. dactylon* mediated silicon dioxide nanoparticles was analyzed at various concentrations from 10 to 50µg/ml and compared with the standard solution of ascorbic acid. The synthesized nanoparticles were mixed with 1ml of deionized water and this mixture was added to 1ml of 1mM DPPH (Periakaruppan *et al.,* 2024). The mixture was placed at room temperature for 30min. After 30 min of incubation in dark conditions, all mixtures were measured at 517 nm using a UV– visible spectrophotometer (Shimadzu UV-1800, Japan). The DPPH scavenging activity was calculate based on the (Periakaruppan *et al.,* 2025).

## Results and Discussion

### Identification of actinobacterial strain RGS17

The physiological characteristics of RGS17 were evaluated. The strain RGS17 grew well in media supplemented with malt extract and yeast extract on International Streptomyces Project 2 (ISP2). An abundant formation of aerial mycelium with reverse-side pigment. Hyphae with filamental branching with spore surface waves were observed by micromorphological analysis. The similar results were reported in (Parathasarathi *et al.,* 2012). The 16s rRNA sequencing analysis showed that 100% similarity with *Streptomyces hygroscopius* of the NCBI database. The actinobacterial strain was identified as *Streptomyces hygroscopius* (RGS17) with accession number MZ031397 (Fig. 1a & b). The yield of the $SiO_2$ NP's was higher in green synthesis compared to microbial synthesis (Fig. 2).

### Characterization of $SiO_2$ NP's

UV-visible absorption spectroscopy is the most important techniques to characterize the nanoparticles. The highest absorbance at 320nm for the both Sh-SiNPs and *C. dactylon* mediated silica nanoparticles (Fig. 3a and b). It conforms the formation of silica nanoparticles. (Sankareswaran *et al.,* 2022) showed that peak occurrence in the range between 230 and 300 nm in UV spectra because of the surface plasmon resonance nature of silica nanoparticles in the reaction medium. Crystallographic studies of *C. dactylon* and Sh-SiNPs mediated nanoparticles shows the broad and high intensity peak at 2θ angle of 22º corresponds the amorphous nature of silica nanoparticles (Fig. 4a and b). The planar values for Sh-mediated and *C. dactylon* mediated nanoparticles are 111,220 confirms the silicon nanoparticles. More over no sharp peak was observed in other scanning angles starting absence of any ordered crystalline structure. Similar results were reported by (Nayak *et al.,* 2021) who extracted the silica nanoparticles from the rice husk ash. (Babu *et al.,* 2018) reported the broad peak at 22º of 2θ values which indicates the amorphous nature of the Si NP's. (Garg *et al.,* 2022) revealed that synthesized silica nanoparticles confirmed the amorphous nature which is extracted from the bacteria. The FTIR spectra absorbance bands of Sh SiNPs are observed in the region of 400-4000$cm^{-1}$ which are associated 3402, 1645, 1451, 468$cm^{-1}$ (Fig. 5a and b) with the stretching vibrations for C-H, C-C, N-O, O-H respectively. The FTIR analysis of silica nanoparticles reported the band appearing at 662.21$cm^{-1}$ in the spectrum corresponding to the vibration absorption peak of alkanes, aromatic ring, alcohols, phenols, carboxylic acids etc. The similar FTIR peaks were reported in the (Nayak *et al.,* 2021). The spectrum peaks such as 2978, 1558, 1389, 1107, 678$cm^{-1}$ conforms the chemical bonding of Si-O-Si was detected in the *C. dactylon* mediated silica nanoparticles. (Sankareswaran *et al.,* 2022) reports the similar the peaks and conforms the bonding of silicon and oxygen of silica nanoparticles which was derived from *B. pinnatum* leaf extract. In the present study the FTIR results determines the functional groups of capping, reducing and stabilizing agents from microbial and *C. datylon* leaf extract to form the nanomaterials. The shape and morphology of the synthesized Si NPs was determined by the Scanning electron microsope (SEM) analysis. The microscopic images of Sh-Si and *C. datylon* leaf extract mediated NPs clearly shows the distribution and spherical shape of the Si NP's (Fig. 6a and b). The (Patil *et al.,* 2018) produced spherical shape nanoparticles from the rice husk. Gopal *et al.,* (2013) reported that Au NPs were hexagonal, cubical, brick and irregular shapes with aggregate size of 70-1500nm.

### $SiO_2$ NP's on antioxidant activity

The presence of functional groups in the silica nanoparticles may enhance the antioxidant activity. The ascorbic acid (standard) inhibits the free radicals at the concentration of 50 µg/ml shows 97.25%. The concentrations such as 10, 20, 30, 40 and 50µg/ml of Sh-SiNPs mediated silica nanoparticles shows 10.33, 26.53, 67.71, 77.25, 84.32 and *C. dactylon* mediated silica nanoparticles shows 20.33, 36.53, 57.51 70.23 and 80.32% inhibition of the free radicals (Fig. 7).

**Fig.1 a)** Micromorphology of the Streptomyces hygroscopius (RGS17) in scanning electron microscope and b) Phylogenetic analysis of the potential strain RGS-17

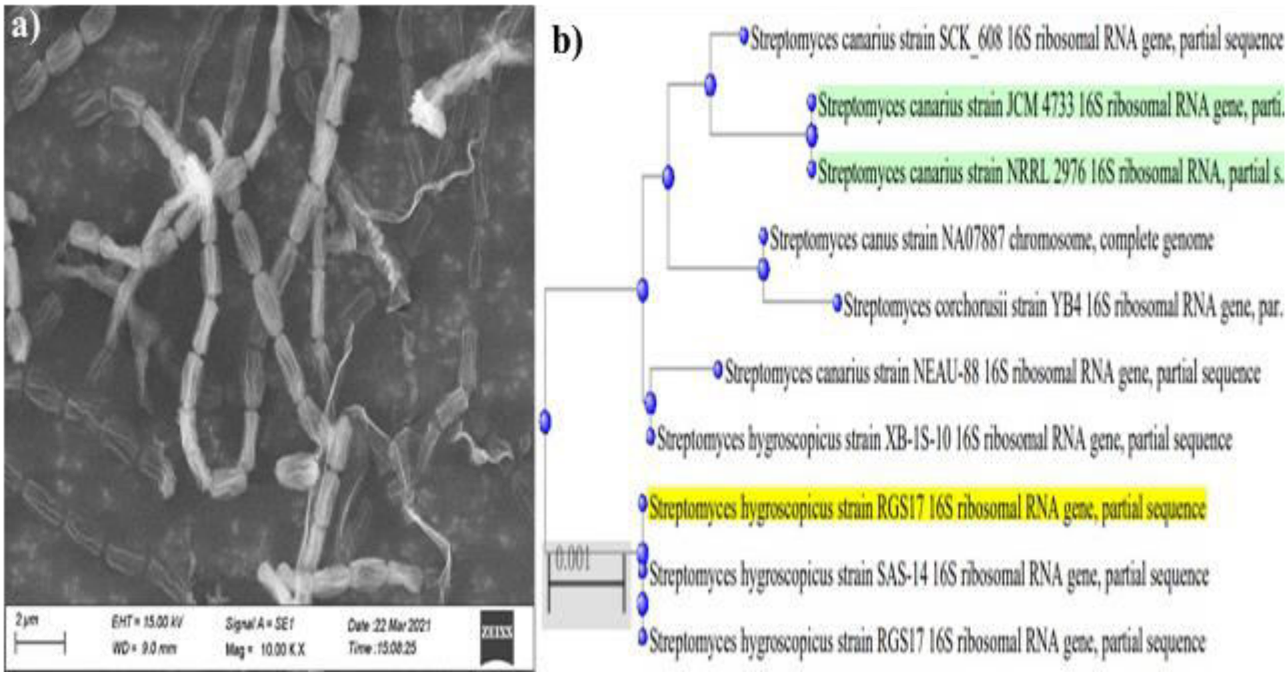


**Fig.2** Yield percentage of the silicon dioxide nanoparticles

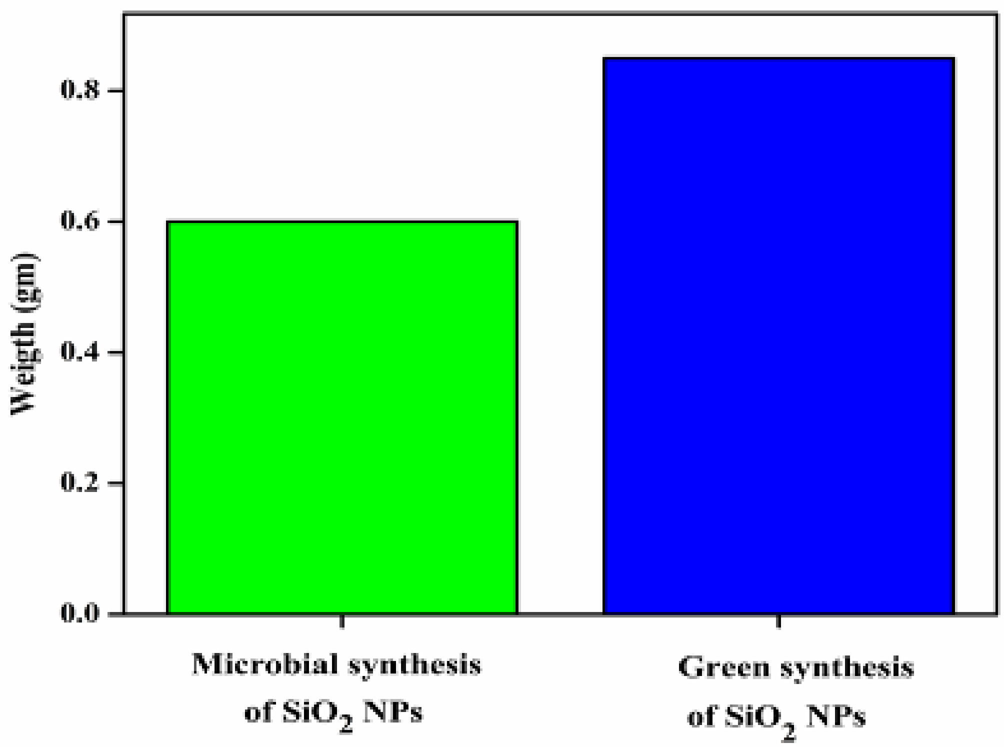

**Fig.3** UV- Spectra of synthesized of nanoparticles (a) Sh mediated $SiO_2$ nanoparticles (b) *C. dactylon* mediated nanoparticles

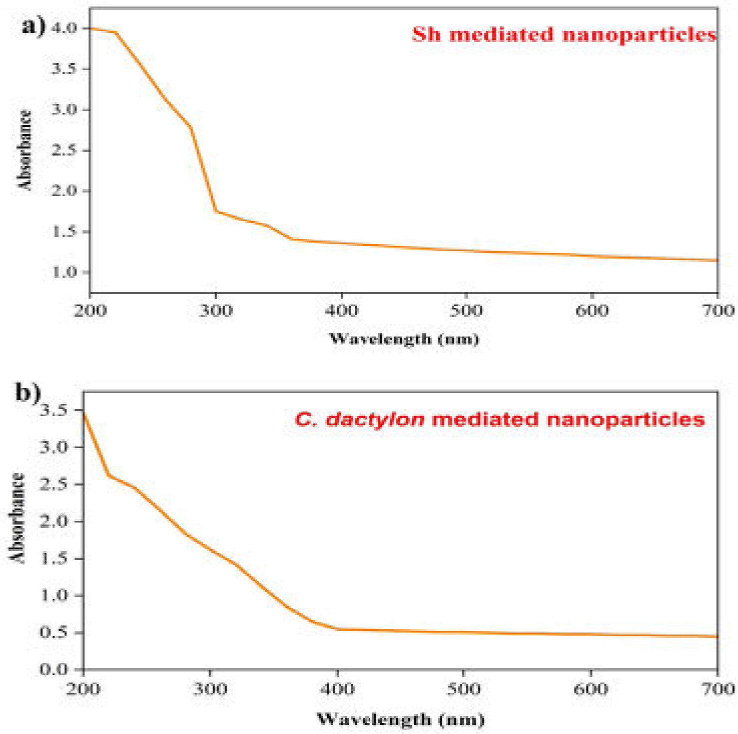


**Fig.4** XRD analysis. (a) Sh mediated $SiO_2$ nanoparticles (b) *C. dactylon* mediated nanoparticles

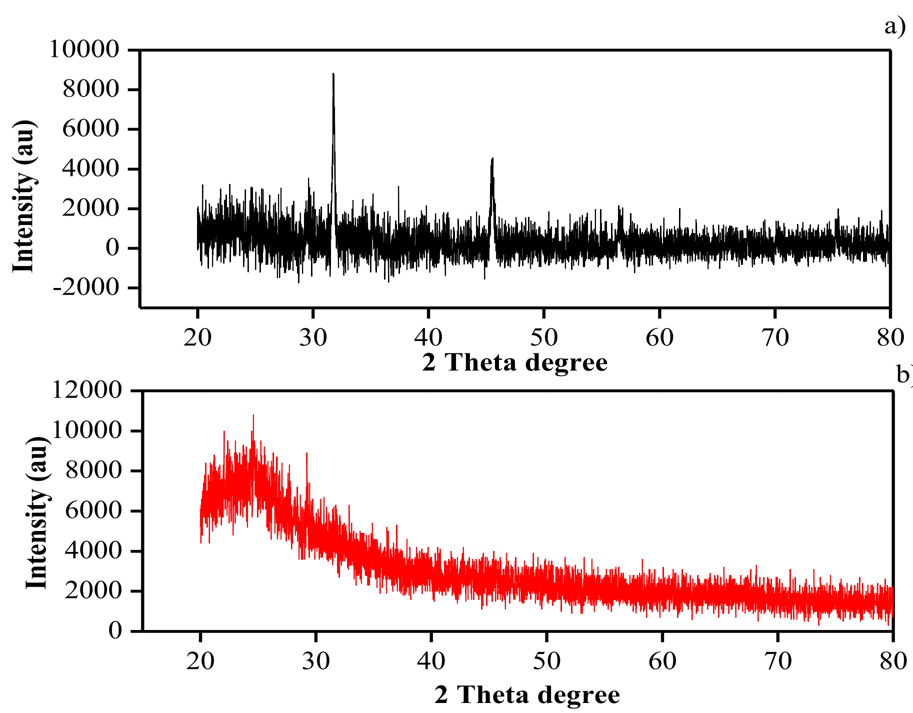

**Fig.5** FTIR analysis (a) Sh mediated $SiO_2$ nanoparticles (b) *C. dactylon* mediated nanoparticles

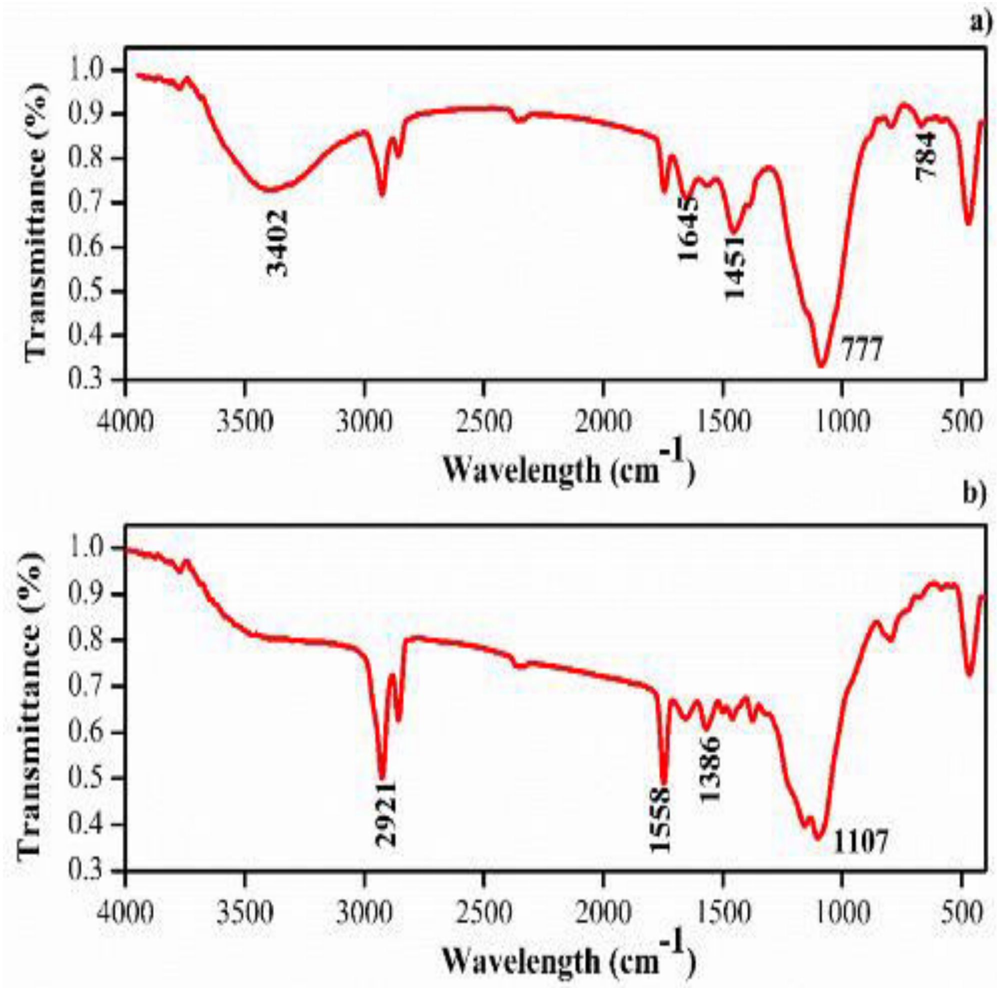


**Fig.6** Scanning electron microscopic image of synthesized Silicon dioxide nanoparticles. (a) Microbial synthesis (b) Green synthesis of silicon dioxide nanoparticles

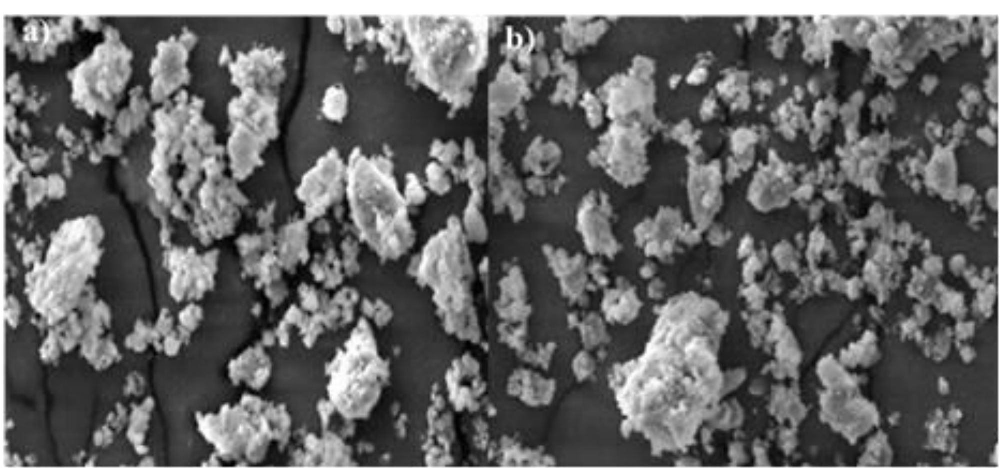

**Fig.7** Anti-oxidant activity of Silicon dioxide nanoparticles

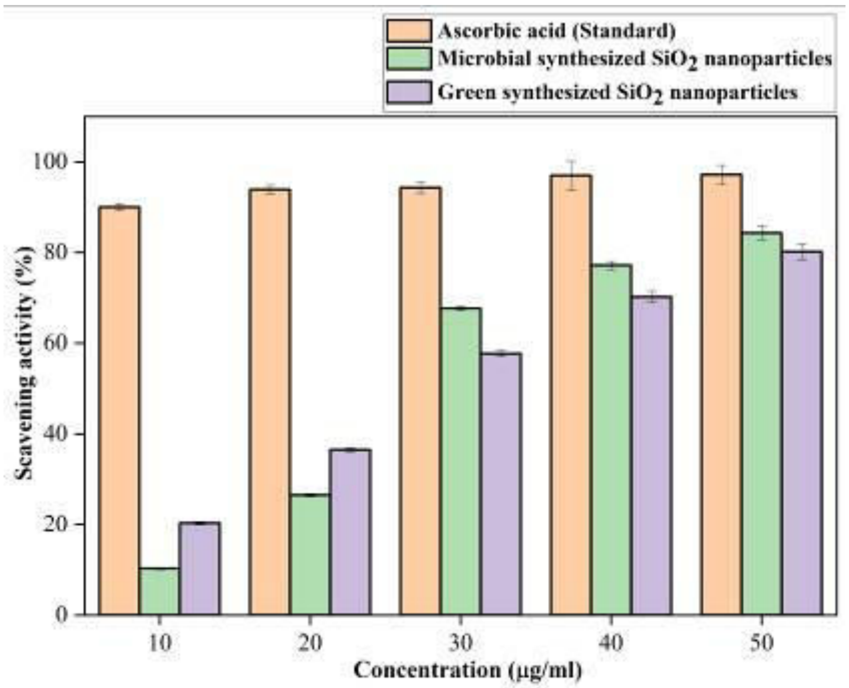


**Fig.8** Anti-bacterial activity of synthesized silicon dioxide nanoparticles (a) *B. cereus* (b) *E. coli* (c) *S. aureus* (d) *K. pneumoniae.* 1: Antibiotic disc, 2: Distilled water, 3: Green synthesized nanoparticles, 4: Microbial synthesized nanoparticles.

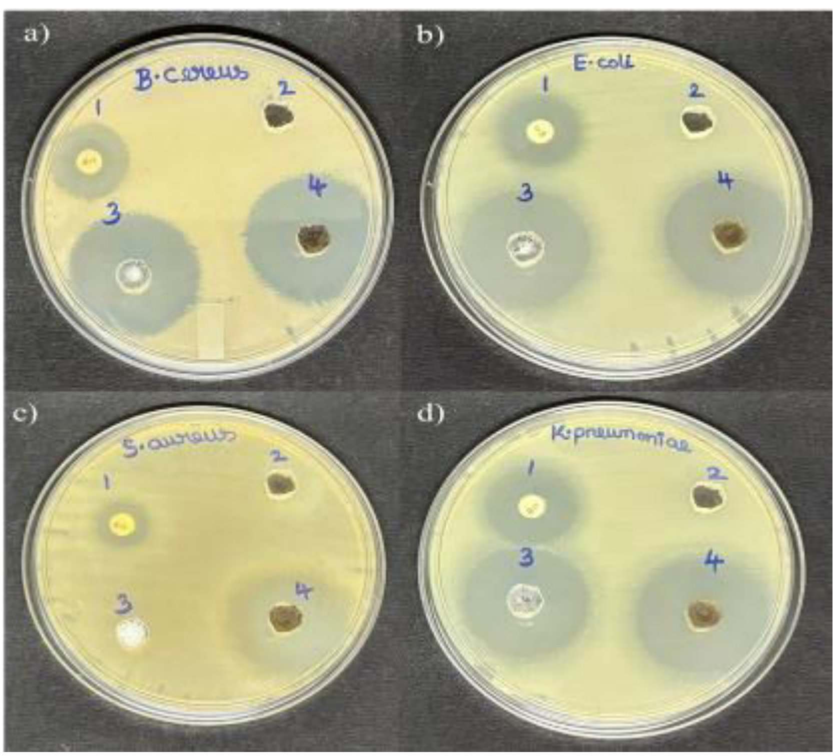

**Table.1** Anti-Bacterial activity of synthesized silicon dioxide nanoparticles

| Zone of inhibition in diameter (mm) | | | | |
|---|---|---|---|---|
| **Name of the organism** | **DMSO** | **Microbial synthesis** | **Green synthesis** | **Chloramphenicol** |
| ***E. coli*** | 0.0 | 9.2 ± 0.1 | 6.1 ± 0.4 | 11.4 ± 0.6 |
| ***B. cereus*** | 0.0 | 10.7 ± 0.3 | 7.4 ± 0.16 | 10.3 ± 0.5 |
| ***K. pneumoniae*** | 0.0 | 6.2 ± 0.1 | 4.0 ± 0.22 | 8.6 ± 0.2 |
| ***S. aureus*** | 0.0 | 5.3 ± 0.2 | - | 8 ± 0.3 |

The present study revealed that Sh mediated SiNPs shows the better antioxidant activity as compared to the *C. dactylon* mediated SiNPs due to the presence of bioactive compounds on the surface of nanoparticles. (Periakaruppan *et al.,* 2025) reported that E. acorides mediated silica nanoparticles have the better antioxidant activity at 350µg/ml. (Alam *et al.,* 2021) revealed that the radical scavenging activity of biosynthesized silver nanoparticles was more effective at R-AgNPs (66%) compared to S-AgNPs (58%). (Palanimuthu *et al.,* 2025) reports that maximum antioxidant activity was obtained at 90µg/ml and lowest at 10µg/ml of $SiO_2$ NPs extracted from *Gracilaria Crassa*.

## $SiO_2$ NP's on antibacterial activity

Performance of silica nanoparticles against *E. coli*, *B. cereus*, *S. aureus and K. pneumoniae* was observed with the formation of inhibitory zones at a final concentration (10µg/ml). The zone of inhibition was good at *B. cereus, E. coli*, *K. pneumoniae* compared to *S. aureus* as shown in (Table. 1). The present study shows higher anti-bacterial activity in Sh mediated silica nanoparticles than *C. dactylon* mediated nanoparticles (Fig. 8). The anti-bacterial activity of $SiO_2$-Ag composites was better than the Ag NPs against Xoo (Cui *et al.,* 2016). The leaf extract of *A. indica* has good anti-bacterial property reported in (Duraisamy *et al.,* 2023). The anti-microbial activity zone of inhibition was good at pigment alone for gram-negative organisms while in the silver nanoparticles zone of inhibition was good for both gram-positive and gram-negative organisms. The anti-bacterial activity was studied for zinc oxide nanoparticles synthesized from *C. dactylon* against *E. coli and P. aeruginosa* which possess high effective in concentration of Cy-da (10ml) ZnO nanoparticles (Meenatchi *et al.,* 2020).

In conclusion, this study focused on the biosynthesis and characterization of silica nanoparticles ($SiO_2$) using *Streptomyces hygroscopicus* (RGS17) and *C. dactylon* leaf extract. The morphological and molecular identification of RGS17 was characterized and identified as identified as *Streptomyces hygroscopicus* (MZ031397). The biosynthesized $SiO_2$ nanoparticles were confirmed through UV-Vis spectroscopy with characteristic absorbance at 320 nm and XRD analysis indicated their amorphous nature. FTIR analysis revealed the presence of various functional groups contributing to the reduction, capping and stabilization of the nanoparticles. SEM analysis confirmed the spherical morphology of both Sh-SiNPs and *C. dactylon*-mediated SiNPs. Compared to plant-mediated SiNPs, antioxidant tests showed that Sh-SiNPs had better free radical scavenging activity.

This is probably because Sh-SiNPs include microbial bioactive chemicals. Additionally, antibacterial activity tests showed that Sh-SiNPs had stronger inhibitory effects against *Escherichia coli* and *Bacillus cereus*, suggesting encouraging medicinal potential. Overall, this work demonstrates the efficiency of actinobacterium-mediated silica nanoparticle manufacturing as a bioactive and sustainable method for antibacterial and antioxidant applications.

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## Author's Contribution

Sona Shanmugasundaram, Nithiya Mohanam and Ayyasamy Pudukkadu Munusamy have equally contributed to this work (Conceptualization, Methodology, Investigation and Original draft Writing)

Revising the draft and manuscript editing: Sona Shanmugasundaram

Pudukadu Munusamy Ayyasamy: Review and Editing

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## Ethics approval

Not applicable.

## Data availability statement

All data generated or analysed in this study are included in this article.

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