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X- Ray diffraction analysis of Spirulina mediated titanium dioxide Nanoparticles

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Abstract
This study explores the synthesis of titanium dioxide nanoparticles (TiO_2NPs) mediated by *Spirulina platensis* (*S. platensis*) and presents the corresponding X-ray diffraction (XRD) results. The analysis of the XRD patterns confirms the successful formation of crystalline nanoparticles, with distinct peaks aligning with the anatase phase of titanium dioxide. The utilization of *S. platensis* as a mediator not only facilitates the generation of TiO_2NPs but also introduces a bio-friendly and sustainable dimension to the synthesis process. The anatase phase is known for its advantageous properties, including photocatalytic activity and stability, suggesting the potential of the synthesized nanoparticles for applications such as environmental remediation, catalysis, and photovoltaic devices. This study contributes valuable insights into the *S. platensis*-mediated synthesis of TiO_2NPs, emphasizing their promising prospects for diverse technological applications. Further research can delve into optimizing synthesis parameters to enhance nanoparticle properties, promoting their effective utilization in various fields.

Keywords: *Spirulina*, TiO_2, X - Ray diffraction, nanoparticles

Introduction
In recent years, researchers have been exploring various avenues to enhance silk production. Silkworms, specifically the mulberry silkworm (*Bombyx mori*), rely exclusively on mulberry leaves for their nutritional requirements. The quantity and quality of nutrients in mulberry leaves can vary based on environmental factors, fertilizer use, mulberry varieties, and cultivation practices. Traditionally, efforts to improve silk production have involved methods such as silkworm hybridization, artificial diets, and the application of phytojuvenoids. However, these approaches have yielded only modest improvements, and the sericulture economy has not seen significant progress. A promising development in the last decade has been the application of nanotechnology in sericulture. Nanotechnology, with its advanced applications in various fields like targeted drug delivery and molecular diagnosis, has found its way into agriculture, including sericulture. Researchers have explored nanotechnology to enhance silk yield, assess mid gut flora, and improve the reproduction ability of silkworms.

Among the various uses of nanoparticles in sericulture, the focus on increasing silk production has gained momentum. Nanoparticles can be synthesized through different methods, with green synthesis being particularly highlighted. Green synthesis involves using plants, microorganisms, or algae, and it is considered environmentally safe, efficient, and profitable. Cyanobacteria, a group of photoautotrophic prokaryotes, have become a significant player in nanoparticle synthesis. In particular, the use of *Spirulina platensis*, a blue-green algae, has been explored. *S. platensis* contains minerals, 18 amino acids, and vitamins, making it a valuable resource. In sericulture, nanoparticles synthesized through *S. platensis* have been shown to activate tissue metabolism and play a crucial role in promoting the biological parameters of the silk gland in silkworm larvae (Ni *et al.*, 2015) [2].

In conclusion, the integration of nanotechnology into sericulture, especially through the environmentally friendly approach of green synthesis using cyanobacteria like *Spirulina platensis*, holds great potential for improving silk production and advancing the sericulture economy.

Materials and Methods

Preparation of aqueous extraction of *S. platensis*

To obtain the aqueous extract of *S. platensis*, approximately 10g of finely ground *S. platensis* powder was heated in 100 ml of deionized water at 90 °C for 45 minutes. Following this, the solution underwent filtration through Whatman filter paper No. 1 to eliminate debris. The resulting clear, green-colored solution was then stored at 4-8 °C for subsequent experiments (Some *et al.*, 2019) [3].

Synthesis of titanium dioxide nanoparticles

Spirulina mediated TiO_2NPs were synthesised utilizing 0.01 mM titanium dioxide and aqueous extract of *S. platensis* as bio-reductant and capping agent in a green synthesis. Aqueous extract of 20 ml was added to 80 mL of 0.01 M TiO_2 solution, which was kept at room temperature for 6 hours with continuous stirring in a hotplate magnetic stirrer. A change in colour to confirmed the production of TiO_2NPs. FTIR was used to characterize the green synthesised *Spirulina*-mediated TiO_2NPs.

Characterization

X-Ray Diffraction (XRD): The green synthesised *S. platensis* mediated TiO_2NPs were characterized for their physical structure using X-ray powder diffractometer (Brukers AXS D8 advance diffractometer, Mumbai, India) equipped with a SSD-160 detector with nickel filter generating Cu Kα radiation having wavelength was 1.54 Å. The analysis was conducted at 45 kV, 20 mA and with the scan angle (2θ) from 5° to 60°. The Segal equation was used to calculate the crystallinity index (Xc) as shown below:

$$\text{Percent crystallinity} = \frac{\text{I002} - \text{Iam}}{I002} \times 100$$

Where, $I00_2$ and I am are the peak intensities at the crystalline and amorphous regions respectively.

The phase development and crystallinity of *Spirulina* induced TiO_2NPs were studied using X-Ray Diffraction, an analytical technique. Smart Lab was used to record the XRD pattern of produced *Spirulina*-mediated TiO_2NPs. Powder X software was used to compute the lattice parameters. The Scherrer's equation was used to compute the particle size (d spacing value) of the sample (Sun *et al*., 2000) [4].

Results

The XRD analysis was done to confirm the crystalline nature of *S. platensis* mediated TiO_2NPs. The fine sample of nanoparticles was placed on the XRD grid, and the crystallinity was determined (Fig. 1). The peaks appeared at 2θ values ranging from 25 to 90º. The XRD pattern of *S. platensis* mediated TiO_2NPs were observed at 27.79, 36.45, 41.57, 44.41, 54.65, 57.01, 63.11, 64.39, 69.22, 70.09, 76.88, 82.61, 84.47 and 88.01degree, it indicated the formation of good crystalline titanium dioxide with anatase phase shape. The prominent peak at 27.79 in the XRD pattern of green synthesised TiO_2NPs was only connected with the crystallographic plane of TiO_2 anatase. The final material's stoichiometry was highly dependent on the partial pressure used during the synthesis. As a result, synthesised TiO_2NPs exhibit a variety of stoichiometries.

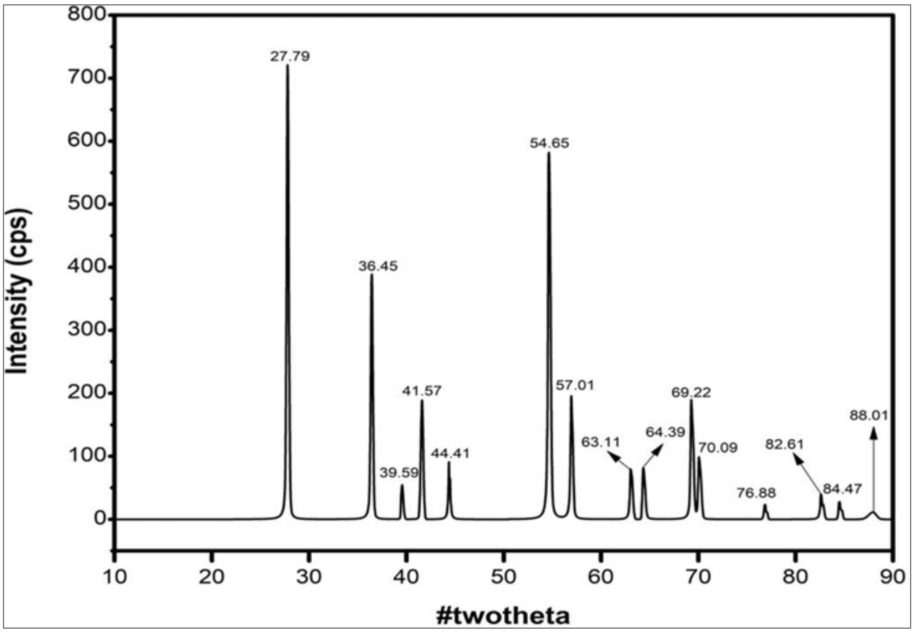

Fig 1: XRD pattern of *S. platensis* mediated TiO_2NPs

Discussion

X-Ray diffraction was used to evaluate the composition, structure and crystal phase of synthesised NPs. The present investigation *S. platensis* mediated TiO_2NPs revealed the crystallinity patterns which correspond to the anatase phases of TiO_2NPs. Similar results were also observed by Hariharan *et al.* (2017) [1] who investigated the X-ray diffraction of TiO_2NPs using X-rays with a wavelength of 1.54Å. The XRD pattern of *Cynodon dactylon* powder was analysed, and the diffraction peaks were perfectly assigned to anatase TiO_2, indicating the samples crystalline structure. Rajeshkumar (2019) [6] used XRD to confirm the crystalline nature and particle size of the *Cassia fistula* mediated TiO_2NPs, where he observed the Face-centered cubic (FCC) structure of the NPs showing weak broadened wurtzite structure as previously reported by Vijayakumar *et al*. (2017) [5].

Conclusion

In conclusion, the X-ray diffraction (XRD) results obtained from the synthesis of titanium dioxide nanoparticles (TiO_2NPs) using *Spirulina platensis* (*S. platensis*) as a mediator indicate the successful formation of crystalline nanoparticles. The prominent diffraction peaks observed in the XRD pattern correspond to the anatase phase of titanium dioxide. This crystalline structure is indicative of the high-quality and well-defined nature of the synthesized TiO_2NPs. The utilization of *S. platensis* as a mediator in the synthesis process not only facilitated the formation of titanium dioxide nanoparticles but also suggests the potential bio-friendly and sustainable approach for nanoparticle synthesis. The anatase phase of TiO_2 is known for its favorable properties, including photocatalytic activity and stability, making the synthesized nanoparticles promising candidates for various applications, such as environmental remediation, catalysis, and photovoltaic devices. Overall, the findings of this study contribute to the understanding of *S. platensis*-mediated TiO_2NP synthesis and highlight the potential of these nanoparticles for diverse technological applications. Further research can explore and optimize the synthesis parameters to enhance the properties and performance of the TiO_2NPs, paving the way for their practical implementation in various fields

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