

A Review on Green Synthesis of TiO₂ Nanoparticles Using Plant Extract and Their Photocatalytic Activities

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Structured Abstract

Background: The eco-friendly synthesis of titanium dioxide (TiO₂) nanoparticles (NPs) using plant extracts offers a sustainable alternative to traditional chemical methods, which often involve toxic reagents and produce harmful by-products. This method utilises naturally occurring bioactive compounds in plants, such as flavonoids, phenolics, alkaloids, and terpenoids, as reducing and stabilising agents during nanoparticle formation. This approach not only significantly reduces the environmental footprint of nanoparticle synthesis but also improves photocatalytic efficiency by enhancing surface characteristics and crystallinity. These photocatalysts hold strong potential in diverse applications, including wastewater treatment, air purification, and the degradation of organic pollutants, aligning with global sustainability goals.

Methods: For this review, credible databases including ScienceDirect, Scopus, and Google Scholar were employed. Over 25 peer-reviewed articles from the past decade were selected using keywords like “green synthesis TiO₂ nanoparticles,” “plant extract TiO₂,” “photocatalytic activity,” and “sustainable nanotechnology.” Non-peer-reviewed sources and irrelevant studies were excluded from the analysis.

Results: TiO₂ nanoparticles synthesised using plant extracts such as *Aloe vera*, *Allium cepa*, and *Citrus sinensis* have shown strong photocatalytic activity, degrading pollutants such as methylene blue (up to 90% in 4 hours under UV light) and ibuprofen. This efficiency is attributed to their high surface area and anatase phase. Advanced extraction methods, such as ultrasonic and microwave-assisted techniques, are more efficient and eco-friendly than traditional methods, such as maceration and Soxhlet extraction. However, inconsistent phytochemical content, lack of standardised protocols, and limited use of advanced characterisation tools (e.g., XRD, UV-Vis) result in varied particle sizes (7–100 nm) and structures. Standardised methods and HRTEM analysis are essential for improving reproducibility and scalability.

Conclusion: The green synthesis of TiO₂ nanoparticles via plant extracts marks a significant advancement in sustainable nanotechnology, offering a cost-effective, non-toxic, and environmentally responsible alternative to conventional methods. Despite promising results, the field faces limitations such as inconsistent particle size, variability in plant composition, and lack of synthesis standardisation. Moving forward, adopting standardised synthesis parameters and integrating advanced analytical techniques will be essential for achieving consistent nanoparticle properties.

Keywords: green synthesis, TiO₂, plant extract, photocatalytic activity

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