IJARSCT
ISSN: 2581-9429
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Volume 6, Issue 5, June 2026
Impact Factor: 8.2

Eco-Friendly Synthesis of 14-Aryl-14h-Dibenzo[A,J] Xanthene Derivatives Mediated by Tin Oxide Nanoparticles

Nilam Pal[1], Smita Tandale[2], Maryappa Sonawale[3], Gurumeet Wadhawa[4], Chetana Tumade[5], Aamod Thakkar[6]
[1] Student, P.G. Department of Chemistry
[2,3,4,5] Assistant Professors, Department of Chemistry
[6] I/C Principal
Veer Wajekar College, Phunde, Uran

Abstract: *The present investigation describes an eco-friendly and efficient methodology for the synthesis of 14-Aryl-14H-dibenzo[a,j]xanthene derivatives using tin oxide nanoparticles (SnO_2 NPs) as heterogeneous nanocatalysts. Green nanocatalysis has emerged as an important field in sustainable organic synthesis because it minimizes environmental pollution, reduces hazardous chemical usage, and improves reaction efficiency. In the present study, tin oxide nanoparticles were synthesized using tamarind leaf extract through a green synthetic route, where plant phytochemicals acted as natural reducing and stabilizing agents.*

The synthesized nanoparticles were characterized using UV–Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), and X-ray Diffraction (XRD) analysis. UV–Visible spectroscopic analysis confirmed nanoparticle formation through characteristic absorption bands, while FTIR studies revealed metal–oxygen stretching vibrations corresponding to Sn–O bonds. SEM analysis showed nanosized spherical particles with porous morphology, and XRD analysis confirmed the tetragonal rutile crystalline structure of SnO_2 nanoparticles.

The synthesized tin oxide nanoparticles were effectively utilized as reusable heterogeneous nanocatalysts in the sonochemical synthesis of substituted dibenzoxanthene derivatives from aromatic aldehydes and β-naphthol. The developed methodology exhibited several advantages including high catalytic efficiency, shorter reaction time, excellent product yield, catalyst recyclability, and environmentally benign reaction conditions. The synthesized dibenzoxanthene derivatives were further characterized using FTIR, UV–Visible spectroscopy, ^1H NMR, and ^{13}C NMR spectroscopy. The present study demonstrates the significant role of tin oxide nanoparticles in sustainable heterocyclic synthesis, sonochemistry, and green organic transformations.

Keywords: Green chemistry, tin oxide nanoparticles, dibenzoxanthenes, nanocatalysis, heterocyclic compounds, sonochemistry, sustainable synthesis.

I. INTRODUCTION

Green chemistry has emerged as an important approach for developing sustainable and environmentally friendly synthetic methodologies. It mainly focuses on minimizing the use of hazardous substances, reducing chemical waste generation, improving atom economy, and designing eco-friendly reaction processes. Conventional organic synthesis often involves toxic solvents, corrosive catalysts, harsh reaction conditions, and environmentally hazardous reagents,

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 5, June 2026 Impact Factor: 8.2

which may create serious environmental and safety concerns. Therefore, sustainable synthetic approaches have gained significant importance in modern chemical research.

Nanotechnology has also become a rapidly advancing field because nanoparticles possess unique physicochemical properties such as high surface area, enhanced catalytic activity, improved selectivity, and faster reaction rates compared to bulk materials. Due to these advantageous properties, metal oxide nanoparticles are extensively utilized in catalysis, environmental remediation, drug delivery systems, sensors, and various organic transformations. Their high surface reactivity and recyclability make them promising materials for green organic synthesis.

Among important heterocyclic compounds, 14-Aryl-14H-dibenzo[a,j]xanthene derivatives have attracted considerable attention because of their diverse biological and industrial applications. These compounds exhibit various biological activities including antimicrobial, anticancer, antioxidant, antiviral, anti-inflammatory, and analgesic properties. In addition to pharmaceutical importance, xanthene derivatives are widely used in fluorescent dyes, laser technologies, pigments, optical sensors, and photodynamic therapy because of their excellent photophysical characteristics.

Tin oxide nanoparticles are important semiconductor materials possessing high catalytic efficiency, thermal stability, low toxicity, chemical stability, and semiconducting behavior. As heterogeneous catalysts, SnO_2 nanoparticles provide several advantages including high surface activity, reusable catalytic sites, shorter reaction time, and higher product yield. These properties make tin oxide nanoparticles highly suitable for sustainable catalytic applications and environmentally benign organic synthesis.

II. OBJECTIVES OF THE STUDY

The primary objective of the present study was to synthesize tin oxide (SnO_2) nanoparticles using eco-friendly and sustainable synthetic methods and to characterize the synthesized nanoparticles using various spectroscopic and analytical techniques. Another major objective was to utilize the prepared SnO_2 nanoparticles as efficient heterogeneous nanocatalysts for the synthesis of dibenzoxanthene derivatives.

The study also aimed to develop a sustainable one-pot synthetic methodology with reduced environmental impact and improved reaction efficiency. In addition, efforts were made to minimize environmental pollution associated with conventional organic synthesis and to enhance catalytic efficiency through the application of nanotechnology. The use of reusable tin oxide nanocatalysts was intended to provide greener reaction conditions, shorter reaction times, and improved product yields in sustainable heterocyclic synthesis.

III. GREEN SYNTHESIS OF TIN OXIDE NANOPARTICLES

The green synthesis of tin oxide nanoparticles was carried out using tamarind leaf extract as a natural reducing and stabilizing agent. Tamarind leaves contain various phytochemicals such as flavonoids, tannins, polyphenols, alkaloids, and reducing sugars, which play an important role during nanoparticle formation. These bioactive compounds act as reducing agents for the conversion of metal ions into nanoparticles, while simultaneously functioning as stabilizing and capping agents to prevent particle aggregation and improve nanoparticle stability.

The green synthetic approach offers several advantages over conventional chemical methods, including eco-friendly processing, non-toxic reaction conditions, reduced chemical waste generation, and low-cost synthesis. Therefore, plant-mediated synthesis of tin oxide nanoparticles represents a sustainable and environmentally benign method for nanoparticle production and green nanocatalysis.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 5, June 2026
Impact Factor: 8.2

Materials Required

The chemicals used in the present investigation included tin chloride dihydrate, sodium hydroxide, ethanol, β-naphthol, various aromatic aldehydes, and distilled water. Tin chloride dihydrate was used as the precursor for the synthesis of tin oxide nanoparticles, while sodium hydroxide was used for pH adjustment during nanoparticle formation. Ethanol and distilled water were used as solvents and washing agents during purification processes. β-Naphthol and substituted aromatic aldehydes were utilized as starting materials for the synthesis of dibenzoxanthene derivatives. All chemicals used were of analytical reagent grade.

Various analytical instruments and laboratory apparatus were employed during synthesis and characterization studies. A UV–Visible spectrophotometer was used for optical characterization of the synthesized nanoparticles, while FTIR spectroscopy was used for identification of functional groups and confirmation of Sn–O bond formation. Surface morphology and particle size were analyzed using a scanning electron microscope (SEM), and crystalline structure was determined using an X-ray diffractometer. An ultrasonic bath was used for sonochemical synthesis of dibenzoxanthene derivatives, and a muffle furnace was employed for calcination of nanoparticles.

Synthesis of SnO_2 Nanoparticles

The green synthesis of tin oxide nanoparticles was carried out using tamarind leaf extract as a natural reducing and stabilizing agent. Fresh tamarind leaves were washed thoroughly, chopped into small pieces, and boiled in distilled water for about 20–30 minutes to obtain the plant extract. The extract was filtered and stored for further use in nanoparticle synthesis.

Tin chloride was dissolved in distilled water to prepare a homogeneous precursor solution. Tamarind leaf extract was then added dropwise into the tin precursor solution under continuous stirring conditions for about 2–3 hours. A visible color change in the reaction mixture indicated nanoparticle formation. Subsequently, the pH of the solution was adjusted to 9–10 using sodium hydroxide solution, resulting in the formation of a white precipitate.

The obtained product was centrifuged and repeatedly washed using distilled water and ethanol to remove impurities and unreacted substances. The purified precipitate was dried at 80–100°C and further calcined at 400–500°C to obtain crystalline tin oxide (SnO_2) nanoparticles. The formation of crystalline SnO_2 nanoparticles was confirmed through characterization studies.

IV. CHARACTERIZATION OF TIN OXIDE NANOPARTICLES

UV–Visible Spectroscopy

UV–Visible spectroscopic analysis was carried out to study the electronic transitions and optical properties of the synthesized tin oxide nanoparticles. The observed absorption bands in the range of 220–240 nm were attributed to charge transfer transitions, while absorption peaks between 280–320 nm corresponded to characteristic SnO_2 nanoparticle absorption. These spectral features confirmed the successful formation of tin oxide nanoparticles and indicated their semiconducting behavior. The broad absorption profile further suggested the nanoscale nature of the synthesized particles.

FTIR Analysis

FTIR analysis was performed to identify the functional groups associated with the synthesized nanoparticles and to confirm Sn–O bond formation. The broad absorption peak observed at 3425 cm^{-1} corresponded to O–H stretching vibrations, while the peak at 2924 cm^{-1} was assigned to C–H stretching vibrations. The absorption band observed at 1631 cm^{-1} indicated C=O stretching vibrations of phytochemical residues present on the nanoparticle surface. A characteristic absorption band at 623 cm^{-1} corresponded to Sn–O stretching vibrations, confirming the formation of tin oxide nanoparticles. The presence of organic functional groups indicated phytochemical stabilization and capping of the nanoparticles.

Scanning Electron Microscopy (SEM)

SEM analysis revealed that the synthesized SnO_2 nanoparticles possessed spherical morphology with porous surface structure and nanoscale particle dimensions. Slight agglomeration of nanoparticles was also observed due to high surface energy. The porous morphology and high surface area of the nanoparticles are advantageous for catalytic applications because they enhance catalytic efficiency and improve reaction rates during organic transformations.

X-Ray Diffraction (XRD) Analysis

X-ray diffraction analysis was carried out to determine the crystalline structure and phase purity of the synthesized tin oxide nanoparticles. The analysis follows Bragg's law:

V. RESULTS AND DISCUSSION

The synthesized SnO_2 nanoparticles exhibited excellent catalytic efficiency in the sonochemical synthesis of dibenzoxanthene derivatives. The nanocatalysts significantly accelerated the reaction rate, improved product yield, enhanced selectivity, and reduced overall reaction time compared to conventional catalytic systems. The high surface area and active catalytic sites present on the nanoparticles contributed to improved catalytic performance during the condensation and cyclization reactions.

The effect of substituents on the aromatic aldehydes was also investigated. Aromatic aldehydes containing electron-donating groups such as $–OCH_3$ and $–CH_3$ showed increased reaction efficiency and produced higher yields due to enhanced electron density and improved reactivity. In contrast, electron-withdrawing substituents such as $–NO_2$ and –Cl slightly reduced the reaction rate because of decreased electrophilic activation; however, these substrates still provided acceptable yields and good product purity.

The sonochemical method offered several advantages including eco-friendly reaction conditions, reduced energy consumption, faster reaction rates, improved mass transfer, and minimal solvent usage. Ultrasonic irradiation enhanced reaction efficiency through acoustic cavitation and localized high-energy conditions, thereby making the synthetic process more sustainable and environmentally benign.

VI. CONCLUSION

The present study successfully demonstrated the green synthesis of tin oxide nanoparticles using tamarind leaf extract through an environmentally friendly and sustainable synthetic approach. Characterization studies using UV–Visible spectroscopy, FTIR, SEM, and XRD confirmed the successful formation of crystalline SnO_2 nanoparticles with nanoscale dimensions. The synthesized SnO_2 nanoparticles acted as efficient heterogeneous nanocatalysts in the synthesis of 14-Aryl-14H-dibenzo[a,j]xanthene derivatives.

The sonochemical synthetic methodology provided several advantages including shorter reaction times, excellent product yields, and environmentally friendly reaction conditions. Spectroscopic characterization further confirmed the successful synthesis of dibenzoxanthene derivatives. Overall, the present work represents an important advancement in sustainable heterocyclic synthesis, green nanocatalysis, and environmentally benign organic transformations.

VII.FUTURE SCOPE

Future research in this field may focus on detailed biological evaluation of the synthesized dibenzoxanthene derivatives, including anticancer and antimicrobial screening studies. Further investigations may also emphasize catalyst recyclability optimization, industrial-scale synthesis, and development of advanced nanocatalysts with enhanced catalytic activity and stability for sustainable organic synthesis applications.

REFERENCES

1. Anastas PT, Warner JC. *Green Chemistry: Theory and Practice*. Oxford University Press; 1998.
2. Heravi MM, et al. Recent advances in xanthene synthesis. *RSC Adv*. 2014;4:50090–50111.
3. Kidwai M, et al. Ecofriendly synthesis of xanthenes using reusable catalysts. *J Mol Catal A*. 2006;252:135–141.
4. Pavia DL, Lampman GM, Kriz GS. *Introduction to Spectroscopy*. Cengage Learning; 2015.
5. Silverstein RM, Webster FX, Kiemle DJ. *Spectrometric Identification of Organic Compounds*. Wiley; 2014.
6. Narayanan R, El-Sayed MA. Catalysis with nanoparticles. *Nano Lett*. 2004;4:1343–1348.
7. Zhang J, Liu J, Peng Q. Metal oxide nanomaterials for catalysis. *Chem Soc Rev*. 2014;43:315–328.
8. Mukherjee P, Ahmad A, Mandal D. Green synthesis of nanoparticles. *J Nanotechnol*. 2011.
9. Deshmukh RR, Salunkhe SD. Ultrasonic assisted synthesis of heterocyclic compounds. *Ultrason Sonochem*. 2015;27:628–634.
10. Rostamizadeh S, et al. SnO_2 nanoparticle-mediated green synthesis. *Catal Commun*. 2012.