



Share Your Innovations through JACS Directory

Journal of Nanoscience and Technology

Visit Journal at <https://www.jacsdirectory.com/jnst>

ISSN: 2455-0191



Green Synthesis of Zinc Oxide Nanoparticles using *Coriandrum sativum* Leaves Extract and Its Applications in Organic Synthesis

Shankaraiah G. Konda*, Pratiksha A. Rahane, Rakesh Borse, Pradip S. Shelar

P.G. and Research Center in Chemistry, Department of Chemistry, K.J. Somaiya College of Arts, Commerce and Science (Affiliated to Savitribai Phule Pune University, Pune), Kopargaon – 423 601, Maharashtra, India.



ARTICLE DETAILS

Article history:

Received 25 July 2026

Accepted 21 August 2026

Available online 26 August 2026

Keywords:

Green Synthesis

Coriandrum sativum Leaves

Zinc Oxide Nanoparticles

Chalcones

ABSTRACT

In this present work, the synthesis of zinc oxide (ZnO) nanoparticles (NPs) carried out at room temperature via green method (plant mediated) using *Coriandrum sativum* leaf extract. The prepared nanoparticles were characterized by FTIR, UV-Visible, XRD and SEM techniques to confirm its formation. It is observed from the FTIR spectrum that *Coriandrum sativum* leaf extract is significantly rich in different chemical groups such as –OH, –COOH and amine. Absorption UV-spectra analysis of synthesized ZnONPs was performed to study the optical property, found to be the band width of 3.8 eV and to confirm the presence of zinc oxide nanoparticles. The absorption spectrum reveals strong absorption peak at 272 nm within the absorption range 200–650 nm, which confirms formation of ZnO nanoparticles. The XRD pattern shows sharp and narrow diffraction peaks suggest that synthesized product has the good crystallinity with relatively larger crystallites, and signifies the effects of experimental conditions on the nucleation and growth of the crystal. The XRD patterns shows the noticeable peaks corresponding to 2θ values of 31.64° , 34.43° , 36.28° , 47.75° , 56.52° , 63.45° , 67.91° and 69.25° . The calculated value of crystalline size was found to be 60 nm and closely matched with wurtzite structure of ZnO. The SEM images showed that the particles are well shaped and spherical in the size range 30–150 nm, and there is fairly large number of individual small nanoparticles along with very few agglomerated relatively bigger particles. Further, these nanoparticles were applied as green catalyst in the synthesis organic chemistry transformations. ZnONPs used as heterogeneous green catalyst in the preparation of chalcones (E)-N-phenyl-3-(substituted)-acrylamide **3(a-f)** (chalcones) by the condensation of aromatic aldehydes and acetanilide is reported. This method includes, cost effective, high yields, easy workup procedure, short reaction time at room temperature are the main advantages of this procedure is described.

1. Introduction

Metal oxide nanoparticles are of great interest for both fundamental research and technological development [1,2]. Several investigators are trying to develop the proper growth and processing techniques for the synthesis and to manipulate the features of metal oxide nanoparticles (NPs). Among various metal oxide nanomaterials, zinc oxide nanoparticles (ZnONPs) have attracted significant attention because of their excellent optical, electrical, catalytic, and antimicrobial properties [3,4], as well as their chemical stability, biocompatibility, low toxicity, and cost-effectiveness [5,6]. It is worth noting that zinc oxide nanoparticles can be used in various applications such as biotechnology, drug delivery, medical, optical devices, DNA labelling, bio molecular detection, diagnostics [7] optoelectronics, nanogenerators, biosensors, solar cells, photocatalysts lubricants, rubber, photo detectors, cement ceramics sensors [8,9]. The ZnONPs can be synthesized by the chemical, physical, or biological methods. The physical and chemical methods include sol-gel, hydrothermal, chemical precipitation, microwave-assisted synthesis, chemical vapor deposition, and thermal decomposition. However, the chemical and physical methods are expensive due to costly stabilizing/reducing agent and equipment as well as having toxic byproducts. Therefore, green synthesis has been explored as an approach to synthesize metal NPs with controlled size and shape [10]. Green synthesis utilizes pollutant-free chemicals and solvents such as water and natural extracts to synthesize NPs [11]. The green method has no requirement of high temperature for synthesis and calcinations and can be easily scaled up. Recently, adopting eco-friendly protocols to synthesize a wide range of nanoparticles and hybrid materials has become more

popular [12]. In addition, plant-mediated green synthesis has gained much attention due to the use of natural capping agents and the absence of toxic chemicals [13]. Plant leaves are widely regarded as suitable materials for the green synthesis of ZnO nanoparticles because they are rich in phytochemicals, have more H^+ ions to reduce zinc acetate dehydrate (the precursor) into ZnO NPs [14]. Among the various plant species investigated, *Cassia fistula* [15], *Moringa oleifera* [16], *Laurus nobilis* [17], *Caralluma fimbriata* [18], *Vitis labrusca* [19], *Artocarpus heterophyllus* [20], *Aristolochia indica* [21], and *Carica papaya* [22] have been successfully employed for the green synthesis of ZnONPs. Chalcones, chemically known as α,β -unsaturated aromatic ketones, is found to be the biologically active compounds and versatile intermediates in organic synthesis. Chalcone derivatives exhibit diverse pharmacological activities, including anticancer, antimicrobial, anti-inflammatory, antidiabetic, antipyretic, anti-allergic, analgesic, and antimalarial effects [23–26]. In addition to their medicinal significance, chalcones are widely employed in the development of fluorescent probes [27], corrosion inhibitors [28], pesticides [29], and liquid crystalline materials [30,31]. They also act as key synthetic precursors for the preparation of numerous biologically important heterocyclic compounds, such as flavones, isoxazoles, pyrazoles, pyrazolines, pyrimidines, thiazines, and imidazolines [32–37]. The classic method for synthesizing chalcones is the base-catalyzed Claisen–Schmidt condensation reaction [38, 39]. Other notable techniques include microwave irradiation [40] and ultrasound irradiation [41], Suzuki reaction [42], Friedel–Crafts reaction, Photo-Fries rearrangement [43, 44], solvent-free grinding [45, 46] were reported in the literature.

In this context, herein, this paper report green synthesis of ZnO nanoparticles and stabilized using *Coriandrum sativum* (annual herb) leaf extract by the bio reduction method without using any harmful reducing and capping agent. Further, applications of ZnONPs as green catalyst in organic transformations is described. The *Coriandrum sativum* is a medicinal plant also known as 'Dhania' belongs to family *Apiaceae* [47, 48].

*Corresponding Author: kondasg@rediffmail.com (Shankaraiah G. Konda)<https://doi.org/10.30799/jnst.377.26110507>

2455-0191 / JACS Directory©2026. This is an open access article licensed under CC BY 4.0.



2. Experimental Methods

2.1 Materials and Preliminary Characterization

All the chemicals were obtained from commercial sources as analytical grade and used without further purification. The melting points of synthesized products were determined in an open capillary method were uncorrected. Merck, precoated silica gel 60 F₂₅₄ (Aluminum sheets) plates were used for analytical TLC. All known organic products were identified by comparison of their physical and spectral data with those of authentic samples. IR spectra were recorded on FTIR-Shimadzu spectrometer

2.2 Preparation of *Coriandrum sativum* Leaves Extract

Fresh leaves of *Coriandrum sativum* were washed thoroughly 4-5 times with biodegradable and distilled water to remove the dust particles and other unwanted impurities and cut it into fine pieces. The 50 g of dried *Coriandrum sativum* leaves was mixed with 200 mL of deionized water in a 500 mL glass beaker and boiled at 60 °C for 30 minutes. The color of mixture was changed to dark yellow. Then, the mixture was cooled to room temperature and filtered using Whatman filter paper. The filtrate was collected & the extract was stored in glass bottle.

2.3 Synthesis of Zinc Oxide Nanoparticles (ZnONPs)

20 mL of 0.02 M zinc acetate dihydrate (ZnC₄H₆O) was taken to 50 mL distilled water. The mixture was stirred using magnetic stirrer (200 rpm) for 10 min. Thereafter 1 mL of the aqueous leaf extract of *Coriandrum sativum* was added into the solution. The pH of the solution was adjusted to 12 by 2.0 M NaOH until pale white aqueous solution formed. The mixture was stirred again (1000 rpm) for 2 h until white precipitate was formed. The white precipitate was separated by centrifugation (4000 rpm) for 25 min. The precipitate was washed once with 5 mL of distilled water and 95% ethanol for 1 min to remove impurities. The precipitate was dried at 100 °C in an oven for overnight to obtain pale white ZnONPs powder and calcined at 550 °C in furnace for 13 h to obtain fine white ZnO nanoparticles. The schematic way of synthesis of ZnONPs represented in Fig. 1.



Fig. 1 The schematic way of synthesis of zinc oxide nanoparticles (ZnONPs)

2.4 Characterization of ZnO Nanoparticles

The crystal structure of the synthesized nanoparticles was examined with powder X-ray diffraction (XRD) and the pattern were recorded using X-ray diffractometer (Phillips X Pert model) equipped with CuK α radiation ($\lambda = 0.1542$ nm) within the 2θ range of 10° – 70° . Morphological characteristics, size and composition of nanoparticles were determined by scanning electron microscopy (SEM) equipped with the X-Ray energy-dispersive spectrometry (EDX). SEM images were captured on a LEO-435 VP instrument operated at 25 kV. FTIR-Shimadzu spectrometer was used to theorize the functional groups involved in the synthesis. The optical properties of synthesized nanoparticles were deliberated using Shimadzu UV-Visible spectrophotometer.

2.5 Synthesis of (E)-N-Phenyl-3-(Substituted)Acrylamide 3(a-f)

An equivalent mixture of acetanilide (0.005 M) and aromatic benzaldehyde (0.005 M) in methanol (2 mL) was taken in mortar and pestle. The catalyst ZnONPs (0.1 g in 5 mL water) was added drop wise at room temperature. The reaction mixture was grinding for 20-25 minutes. The completion the reaction mixture was monitored by thin layer chromatography (TLC). After completion of the reaction, poured into ice-cold water and neutralized with dilute HCl. The solid obtained was filtered over Buchner funnel and washed freely with distilled water. The crude

<https://doi.org/10.30799/jnst.377.26110507>

product was separated, filtered and crystallized from suitable solvent. The heterogeneous catalyst (ZnONP) was separated as residual part. The yield and melting point of product was recorded.

3. Results and Discussion

The green synthesis of zinc oxide nanoparticles was carried out using *Coriandrum sativum* leaf extract, which contains minerals and vitamins, including calcium, phosphorus, iron, and sodium, as well as organic acids. These bioactive constituents are present in significant amounts and are responsible for the reduction process [49]. Furthermore, the characterization of green-synthesized ZnO nanoparticles using various analytical techniques reveals their structural and optical properties.

3.1 Fourier Transform Infrared Spectroscopy Study (FTIR)

The FTIR spectra of synthesized ZnO nanoparticles was shown in Fig. 2. The spectra were recorded in the series of absorption band 500-4000 cm⁻¹. The band at 3500 cm⁻¹ is attributed to the O-H stretching of hydroxyl group, whereas the stretching frequency observed at 1630 cm⁻¹ identifies the presence of asymmetrical stretching of carboxylate (COO⁻). Broad peak at 1029 cm⁻¹ occurs due to the stretching vibration between C-N bonds of amine. Moreover, absorption band at 548 cm⁻¹ identifies the occurrence of ZnO nanoparticles. Thus, it can be observed from the FTIR spectrum that *Coriandrum sativum* leaf extract is significantly rich in different chemical groups such as -OH, -COOH and amine. This IR spectral data is in agreement with reported literature [50-52].

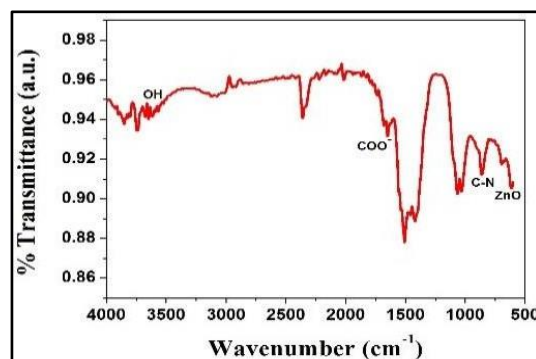


Fig. 2 FTIR spectrum of ZnO nanoparticles synthesized using *Coriandrum sativum* leaf Extract

3.2 Absorption UV-Visible Spectroscopy Study

Absorption UV-spectra analysis of synthesized ZnONPs was performed to study the optical property and to confirm the presence of zinc oxide nanoparticles. The absorption spectrum is shown in Fig. 3. It reveals strong absorption peak at 272 nm within the absorption range 200-650 nm, which confirms formation of ZnO nanoparticles [53]. The band gap energy was determined using Tauc equation $\alpha h\nu = \beta(h\nu - E_g)^m$ for direct band gap material, where, α is the absorption coefficient for direct band gap material, β is the constant and has different values for the different transitions. E_g is the energy gap and $h\nu$ is the photon energy while m denotes an exponent which have values $1/2$, $3/2$, 2 and 3 depending on the electronic transition [54].

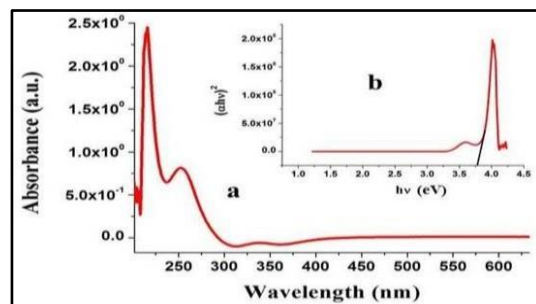


Fig. 3 Absorption spectral analysis of synthesized ZnONPs

Tauc plot as shown in Fig. 3(b)(inset), the photon energy ($h\nu$) on the X axis and a quantity $(\alpha h\nu)^2$ on the Y axis; and extrapolating the linear portion of the curve to the X axis yields the energy band gap of the material. The gap was found to be 3.8 eV which is comparable to the values obtained by others [55,56]. It is found that, our calculated value is higher than that of bulk ZnO (3.3 eV), which indicates that the as prepared ZnO

nanoparticles exhibit strong quantum confinement by modifying valence and conduction bands of ZnO semiconductor.

3.3 X-Ray Diffraction Pattern Study

XRD pattern of synthesized sample is shown in Fig. 4. The sharp and narrow diffraction peaks suggest that synthesized product has the good crystallinity with relatively larger crystallites, and signifies the effects of experimental conditions on the nucleation and growth of the crystal. The XRD patterns shows the noticeable peaks corresponding to 2θ values of 31.64° , 34.43° , 36.28° , 47.75° , 56.52° , 63.45° , 67.91° and 69.25° . The prominent peaks correspond to (hkl) values of (100), (002), (101), (102), (110), (103), (112) and (201). These plane values are closely matched with wurtzite structure of ZnO. Additionally, no characteristic peaks other than the ZnO appears which in turn specify the high purity of our sample. The average crystalline size of nanoparticles was estimated using the Debye-Scherrer formula [57], $D = 0.89\lambda / \beta \cos\theta$, where, λ (1.54 Å) is the wavelength of X-ray, θ being Bragg's diffraction angle and β is the full width at half maximum. The calculated value of crystalline size was found to be 60 nm, which obviously supports the SEM.

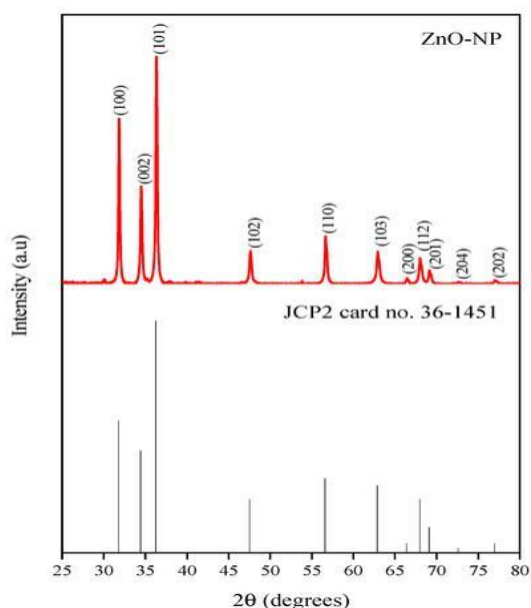


Fig. 4 XRD pattern of synthesised zinc oxide nanoparticles

3.4 Scanning Electron Microscopy Study (SEM)

The typical SEM images of the ZnO nanoparticles are shown in Fig. 5. SEM images showed that the particles are well shaped and spherical in the size range 30–150 nm, and there is fairly large number of individual small nanoparticles along with very few agglomerated relatively bigger particles [58].

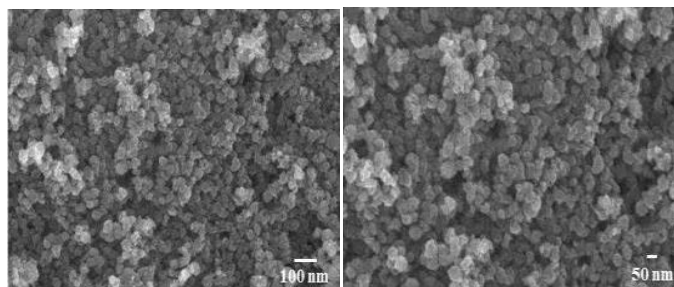
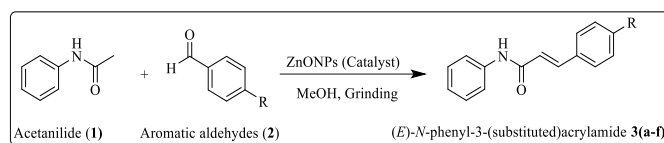


Fig. 5 SEM images of ZnO nanoparticles synthesized using *Coriandrum* leaf extract

3.5 Synthesis of Chalcones by ZnONPs

Further, these synthesized ZnONPs was used as green catalyst for the synthesis of chalcones using Claisen-Schmidt condensation. Here, the condensation of aromatic aldehydes with acetanilide using zinc oxide nanoparticles as catalyst in presence of aqueous methanol at grinding under mortal pastel at room temperature is described (Scheme 1). The time for complete the reaction was 20–30 minutes. The workup procedure and separation of products was easy as shown experimental section. The physical and analytical data of synthesized compounds shown in Table 1. These formation products and characterization were confirmed with reported literature [59].

<https://doi.org/10.30799/jnst.377.26110507>



Scheme 1 Synthesis of (E)-N-phenyl-3-(substituted) acrylamide **3(a-f)** using ZnONPs as green solid catalyst

Table 1 Physical and analytical data of synthesized compounds (**3a-f**)

Entry	R	Mol. Formula	Rx ^a time (min)	Yield (%)	M.P. (°C)
3a	OCH ₃	C ₁₆ H ₁₂ NO ₂	20	88	126–128
3b	CH ₃	C ₁₆ H ₁₅ NO	25	85	158–160
3c	Cl	C ₁₅ H ₁₂ NOCl	20	85	166–168
3d	N(CH ₃) ₂	C ₁₇ H ₁₈ N ₂ O	25	80	132–136
3e	NO ₂	C ₁₅ H ₁₂ N ₂ O ₃	28	75	200–202
3f	H	C ₁₅ H ₁₃ NO	22	82	150–152

4. Conclusion

In the summary, the present methodology is reveals with the green synthesis, zinc oxide nanoparticles carried out at room temperature via green route using *Coriandrum sativum* leaf extract. The prepared nanoparticles were characterized by Fourier transform infrared spectroscopy (FTIR), UV-visible spectroscopy, X-ray diffraction (XRD) and scanning electron microscopy (SEM) to confirm its formation. The absorption spectrum reveals strong absorption peak at 272 nm within the absorption range 200–650 nm, which confirms formation of ZnO nanoparticles. The XRD patterns shows the noticeable peaks corresponding to 2θ values of 31.64° , 34.43° , 36.28° , 47.75° , 56.52° , 63.45° , 67.91° and 69.25° . The calculated value of crystalline size was found to be 60 nm and closely matched with wurtzite structure of ZnO. The SEM images showed that the particles are well shaped and spherical in the size range 30–150 nm. Further, the prepared nanoparticles were applied for the synthesis of organic chemistry transformations. By using ZnONPs as heterogeneous green catalyst in the preparation of chalcones (E)-N-phenyl-3-(substituted)-acrylamide **3(a-f)** (chalcones) by the condensation of aromatic aldehydes and acetanilide has reported. This method includes, cost effective, high yields, easy workup procedure, short reaction time at room temperature are the main advantages of this procedure. These formations of products were confirmed and matched with reported literature data.

Acknowledgements:

The authors are thankful to DBT-Star College Scheme, New Delhi (File No: HRD-11011/18/2024-HRD-DBT) for providing financial support to procurement of equipment and required chemicals for this research work. The authors are also thankful to Head, Department of Chemistry and Principal, K.J. Somaiya College, Kopargaon for providing necessary facilities.

References

- [1] T. Bora, J. Dutta, Applications of nanotechnology in wastewater treatment-A review, J. Nanosci. Nanotech. 14 (2014) 613–626.
- [2] Z. Fan, X. Huang, C. Tan, H. Zhang, Thin metal nanostructures: synthesis, properties, and applications, Chem. Sci. 6 (2015) 95–111.
- [3] S. Ansilin, J. Kavya Nair, C. Aswathy, V. Rama, J. Peter, J. J. Persis, Green synthesis and characterization of copper oxide nanoparticles using *Azadirachta indica* (Neem) leaf aqueous extract, J. Nanosci. Tech. 2 (2016) 221–223.
- [4] Z. Fan, J.G. Lu, Zinc oxide nanostructures: synthesis and properties, J. Nanosci. Nanotech. 5 (2005) 1561–1573.
- [5] M. Swain, D. Mishra, G. Sahoo, A review on green synthesis of ZnO nanoparticles, Discov. Appl. Sci. 7 (2025) 997.
- [6] Z.U. Zango, A. Garba, F.B. Shittu, S.S. Imam, A. Haruna, et al., A state-of-the-art review on green synthesis and modifications of ZnO nanoparticles for organic pollutants decomposition and CO₂ conversion, J. Hazard. Mater. Adv. 17 (2025) 100588.
- [7] M. Singhai, V. Chhabra, P. Kang, D.O. Shah, Synthesis of ZnO nanoparticles for varistor application using Zn-substituted aerosol OT microemulsion, Mater. Res. Bull. 32 (1997) 239–247.
- [8] C.W. Bunn, The lattice dimensions of zinc oxide, Proc. Phys. Soc. 47 (1935) 835–842.
- [9] X.L. Cheng, H. Zhao, L.H. Huo, S. Gao, J.G. Zhao, ZnO nanoparticulate thin film: preparation, characterization, and gas-sensing property, Sens. Actuators B Chem. 102 (2004) 248–252.
- [10] H. Agarwal, S. Venkat Kumar, S. Rajeshkumar, A review on green synthesis of zinc oxide nanoparticles—an eco-friendly approach, Resour. Effic. Technol. 3 (2017) 406–413.

- [11] D. Gnanasangeetha, D.S. Thambavani, One pot synthesis of zinc oxide nanoparticles via chemical and green methods, *Res. J. Mater. Sci.* 1 (2013) 1-8.
- [12] R. Alsubki, H. Tabassum, M. Abudawood, A.A. Rabaan, S.F. Alsobaie, S. Ansar, Green synthesis, characterization, enhanced functionality and biological evaluation of silver nanoparticles based on *Coriander sativum*, *Saudi J. Biol. Sci.* 28 (2021) 2102-2108.
- [13] K.B. Narayanan, N. Sakthivel, Coriander leaf mediated biosynthesis of gold nanoparticles, *Mater. Lett.* 62 (2008) 4588-4590.
- [14] R. Amooaghaie, M.R. Saeri, M. Azizi, Synthesis, characterization and biocompatibility of silver nanoparticles synthesized from *Nigella sativa* leaf extract in comparison with chemical silver nanoparticles, *Ecotoxicol. Environ. Saf.* 120 (2015) 400-408.
- [15] D. Suresh, P.C. Nethravathi, Udayabhanu, H. Rajanaika, H. Nagabhushana, S.C. Sharma, Green synthesis of multifunctional zinc oxide (ZnO) nanoparticles using *Cassia fistula* plant extract and their photodegradative, antioxidant and antibacterial activities, *Mater. Sci. Semicond. Proc.* 31 (2015) 446-454.
- [16] K. Elumalai, S. Velmurugan, S. Ravi, V. Kathiravan, S. Ashokkumar, Green synthesis of zinc oxide nanoparticles using *Moringa oleifera* leaf extract and evaluation of its antimicrobial activity, *Spectrochim. Acta Part A Mol. Biomol. Spectrosc.* 143 (2015) 158-164.
- [17] S. Vijayakumar, B. Vaseeharan, B. Malaikozhundan, M. Shobiya, *Laurus nobilis* leaf extract mediated green synthesis of ZnO nanoparticles: characterization and biomedical applications, *Biomed. Pharmacother.* 84 (2016) 1213-1222.
- [18] P. Mishra, Y.P. Singh, H.P. Nagaswarupa, S.C. Sharma, Y.S. Vidya, et al., *Caralluma fimbriata* extract induced green synthesis, structural, optical and photocatalytic properties of Gd-modified ZnO nanostructure, *J. Alloys Compd.* 685 (2016) 656-669.
- [19] Udayabhanu, G. Nagaraju, H. Nagabhushana, D. Suresh, C. Anupama, G.K. Raghu, S.C. Sharma, *Vitis labrusca* skin extract assisted green synthesis of ZnO superstructures for multifunctional applications, *Ceram. Int.* 43 (2017) 11656-11667.
- [20] C. Vidya, C. Manjunatha, M.N. Chandraprabha, M. Rajshekar, M.A.L. Antony Raj, Hazard-free green synthesis of ZnO nanophotocatalyst using *Artocarpus heterophyllus* leaf extract for the degradation of Congo red dye in water treatment applications, *J. Environ. Chem. Eng.* 5 (2017) 3172-3180.
- [21] K. Steffy, G. Shanthi, A.S. Maroky, S. Selvakumar, Enhanced antibacterial effects of green synthesized ZnO nanoparticles using *Aristolochia indica* against multidrug-resistant bacterial pathogens from diabetic foot ulcer, *J. Infect. Public Health* 11 (2018) 463-471.
- [22] D. Sharma, M.I. Sabela, S. Kanchi, K. Bisetty, A.A. Skelton, B. Honarparvar, Green synthesis, characterization and electrochemical sensing of silymarin by ZnO nanoparticles: experimental and DFT studies, *J. Electroanal. Chem.* 808 (2018) 160-172.
- [23] M.N. Gomes, E.N. Muratov, M. Pereira, J.C. Peixoto, L.P. Rosseto, et al., Chalcone derivatives: promising starting points for drug design, *Molecules* 22 (2017) 1210.
- [24] C. Zhuang, W. Zhang, C. Sheng, W. Zhang, C. Xing, Z. Miao, Chalcone: A privileged structure in medicinal chemistry, *Chem. Rev.* 117 (2017) 7762-7810.
- [25] Y. Fu, D. Liu, H. Zeng, X. Ren, B. Song, D. Hu, X. Gan, New chalcone derivatives: synthesis, antiviral activity and mechanism of action, *RSC Adv.* 10 (2020) 24483-24490.
- [26] K. Mezgebe, Y. Melaku, E. Mulugeta, Synthesis and pharmacological activities of chalcone and its derivatives bearing N-heterocyclic scaffolds: A review, *ACS Omega* 8 (2023) 19194-19211.
- [27] S.C. Lee, N.Y. Kang, S.J. Park, S.W. Yun, Y. Chandran, Y.T. Chang, Development of a fluorescent chalcone library and its application in the discovery of a mouse embryonic stem cell probe, *Chem. Commun.* 48 (2012) 6681-6683.
- [28] S. Ghangas, A.K. Singh, V.C. Anadebe, M. Singh, N. Arshad, et al., Coordination chemistry of chalcones and derivatives and their use as corrosion inhibitors: A comprehensive review, *Coord. Chem. Rev.* 517 (2024) 215985.
- [29] M. Dziagwa-Becker, M. Oleszek, S. Zielińska, W. Oleszek, Chalcones - Features, identification techniques, attributes, and application in agriculture, *Molecules* 29 (2024) 2247.
- [30] S.D. Durgapal, R. Soni, S.S. Soman, A.K. Prajapati, Synthesis and mesomorphic properties of coumarin derivatives with chalcone and imine linkages, *J. Mol. Liq.* 297 (2020) 111920.
- [31] K.D. Katariya, K.J. Nakum, H. Soni, S. Nada, M. Hagar, Imine based four-ring chalcone-ester liquid crystals: Synthesis, characterization, mesomorphic behaviour and DFT approach, *J. Mol. Liq.* 380 (2023) 121719.
- [32] W. Mansour, M. Fettouhi, Q. Saleem, B. El Ali, Robust alkyl-bridged bis(N-heterocyclic carbene)palladium(II) complexes anchored on Merrifield's resin as active catalysts for the selective synthesis of flavones and alkynones, *Appl. Organomet. Chem.* 35 (2021) e6195.
- [33] L.W. Xu, C.G. Xia, X.X. Hu, An efficient and inexpensive catalyst system for the aza-Michael reactions of enones with carbamates, *Chem. Commun.* (2003) 2570-2571.
- [34] X. Jie, Y. Shang, X. Zhang, W. Su, Cu-catalyzed sequential dehydrogenation-conjugate addition for β -functionalization of saturated ketones: Scope and mechanism, *J. Am. Chem. Soc.* 138 (2016) 5623-5633.
- [35] C.M.M. Santos, A.M.S. Silva, Transition metal-catalyzed transformations of chalcones, *Chem. Rec.* 24 (2024) e202400060.
- [36] L.K.C. Anita, S. Ameta, V. Sharma, P.S. Ranawat, Synthesis of pyrazoline derivatives and their pharmacological activities: A review of the last decade, *ChemistrySelect* 9 (2024) e202304483.
- [37] Y.N. Nayak, S.L. Gaonkar, M. Sabu, Chalcones: Versatile intermediates in heterocyclic synthesis, *J. Heterocycl. Chem.* 60 (2023) 1301-1325.
- [38] C. Zhuang, W. Zhang, C. Sheng, W. Zhang, C. Xing, Z. Miao, Chalcone: A privileged structure in medicinal chemistry, *Chem. Rev.* 117 (2017) 7762-7810.
- [39] A. Mouna, O.E.L. Hayat, H. Loubna, B.N.M. Mouad, R.C. Mohamed, et al., Spectroscopic analysis and theoretical comparison of the reactivity of 6-amino-3(R)-benzophenone reactions with acetylacetone, *Chem. Rev. Lett.* 7 (2024) 942-956.
- [40] A.H. Shntaif, Green synthesis of chalcones under microwave irradiation, *Int. J. Chem. Tech Res.* 9 (2016) 36-39.
- [41] V.A. Adole, B.S. Jagdale, T.B. Pawar, A.A. Sagane, Ultrasound promoted stereoselective synthesis of 2,3-dihydrobenzofuran appended chalcones at ambient temperature, *S. Afr. J. Chem.* 73 (2020) 35-43.
- [42] R.G.M. da Costa, F.R.L. Farias, D. Back, J. Limberger, Synthesis of arylated chalcone derivatives via palladium cross-coupling reactions, *Tetrahedron Lett.* 59 (2018) 771-775.
- [43] C. Zhuang, W. Zhang, C. Sheng, W. Zhang, C. Xing, Z. Miao, Chalcone: A privileged structure in medicinal chemistry, *Chem. Rev.* 117 (2017) 7762-7810.
- [44] D. Mulugeta, A review of synthesis methods of chalcones, flavonoids, and coumarins, *Sci. J. Chem.* 10 (2022) 41-52.
- [45] N.M. Rateb, H.F. Zohdi, Atom-efficient, solvent-free, green synthesis of chalcones by grinding, *Synth. Commun.* 39 (2009) 2789-2794.
- [46] G.W.V. Cave, C.L. Raston, Efficient synthesis of pyridines via a sequential solventless aldol condensation and Michael addition, *J. Chem. Soc. Perkin Trans. 1* (2001) 3258-3264.
- [47] A. Verma, S.N. Pandeya, S.K. Yadav, S. Singh, P. Soni, A review on *Coriandrum sativum*: An ayurvedic medicinal herb of happiness, *J. Pharm. Bioallied Sci.* 3 (2011) 28-48.
- [48] S. Ramezani, M. Rahmanian, R. Jahanbin, F. Mohajeri, M.R. Rezaei, B. Solaimani, Diurnal changes in essential oil content of coriander (*Coriandrum sativum* L.) aerial parts from Iran, *Res. J. Biol. Sci.* 4 (2009) 277-281.
- [49] M.N.I. Bhuiyan, J. Begum, M. Sultana, Chemical composition of leaf and seed essential oil of *Coriandrum sativum* L., *Bangladesh J. Pharmacol.* 4 (2009) 150-153.
- [50] Z. Tao, X. Yu, J. Liu, L. Yang, S. Yang, A facile synthesis and photoluminescence of porous S-doped ZnO architectures, *J. Alloys Compd.* 459 (2008) 395-398.
- [51] G. Xiong, U. Pal, J.G. Serrano, K.B. Ucer, R.T. Williams, Photoluminescence and FTIR study of ZnO nanoparticles: The impurity and defect perspective, *Phys. Status Solidi C* 3 (2006) 3577-3581.
- [52] P. Ramesh, A. Rajendran, A. Subramanian, Synthesis of zinc oxide nanoparticles from fruits of *Citrus aurantifolia* by chemical and green methods, *Asian J. Phytomed. Clin. Res.* 2 (2014) 189-195.
- [53] Y.H. Ni, X.W. Wei, J.M. Hong, Y. Ye, Hydrothermal preparation and optical properties of ZnO nanorods, *Mater. Sci. Eng. B* 121 (2005) 42-47.
- [54] R. Bhatt, I. Bhaumik, S. Ganesamoorthy, A.K. Karnal, M.K. Swami, H.S. Patel, P.K. Gupta, Urbach tail and band gap analysis in near stoichiometric LiNbO₃ crystals, *Phys. Status Solidi A* 209 (2012) 176-180.
- [55] S. Talam, S.R. Karumuri, N. Gunnam, Synthesis, characterization, and spectroscopic properties of ZnO nanoparticles, *ISRN Nanotechnol.* 2012 (2012) 372505.
- [56] M.S. Samuel, L. Bose, K.C. George, Optical properties of ZnO nanoparticles, *S.B. Acad. Rev.* 16 (2009) 57-65.
- [57] J.S.J. Hargreaves, Some considerations related to the use of the Scherrer equation in powder X-ray diffraction as applied to heterogeneous catalysts, *Catal. Struct. React.* 2 (2016) 33-37.
- [58] S.P. Goutam, A.K. Yadav, A.J. Das, Coriander extract mediated green synthesis of zinc oxide nanoparticles and their structural, optical and antibacterial properties, *J. Nanosci. Tech.* 3 (2017) 249-252.
- [59] Z.A. Sallal, Preparation and characterization of new heterocyclic derivatives, six and five ring from acetanilide, *J. Sci.* 7 (2020) 87-89.