RASĀYAN *J. Chem.*
Vol. 19 | No. 1 | 476-482 | January-March | 2026
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

ZINC-DOPED COPPER OXIDE NANOPARTICLES COMBINED WITH *Ficus Carica* LEAF EXTRACT REVEAL ANTIOXIDANT AND PHOTOCATALYTIC ACTIVITY

V. Sridhar[1], Tentu Nageswara Rao[2], and Y. Prashanthi[1],✉
[1]Department of Chemistry, Mahatma Gandhi University, Nalgonda, TS-508254.
[2]Department of Analytical Chemistry, Isosphere Biosciences Pvt Ltd., Plot No. 443, Sriram Nagar Colony, Rampally, Secundrabad, Telangana-501301, India.
✉Corresponding author: dryprasanthi@gmail.com

ABSTRACT
A hopeful variation to the traditional chemical method is the use of medicinal plant extract for the synthesis of metal oxide nanoparticles. The application of *Ficus carica* leaf extract of Zinc doped Copper oxide nanoparticles synthesised using a green approach was discussed in this paper. SEM, TEM, EDX, XRD crystallography and FT-IR spectroscopy were used to characterise the synthesized product. The product was synthesized in mixed form with a size of 43-57 nm, according to the characterization methods. In addition, the product's antioxidant and photocatalytic activity was investigated, and it was discovered that the nanoparticle has exceptional antioxidant activity. The photocatalytic activities for degradation efficiency of RhB were 100% after 30 minutes of using prepared *Ficus carica* leaf extract of Zinc doped Copper oxide nanoparticles in water under visible light. Rhodamine B degradation with Zinc doped Copper oxide nanoparticles yielded the best results at a pH of 7.0, a catalyst dosage of 0.2g, and a dye concentration of 10 µg/mL.
Keywords: *Ficus Carica* Leaf Extract, Green Synthesis, Zinc-Doped Copper Oxide Nps, Photocatalytic Activity, Antioxidant Activity, XRD, TEM.
RASĀYAN *J. Chem.*, Vol. 19, No.1, 2026

INTRODUCTION

Owing to its potential applications, nanotechnology has provided the world with new possibilities and a wider perspective on what humanity can achieve through the manipulation of materials at the nanoscale, leading to a global paradigm shift in life.[1-5] Nanoparticles (NPs) are characterised by a significant surface-to-volume ratio when compared to their bulk counterparts, making them more appropriate for application-focused performances.[6] These nanoparticles are extensively utilised in biomedical devices, cosmetics, environmental remediation, photocatalysis, electronics, energy storage, automobiles, medicine, information technology, and agriculture, due to their unique properties.[7-13] Among the numerous types of NPs, metal oxide NPs are regarded as particularly important because of their unique chemical, physical, and biological properties. As a result, the role of plant extracts in the synthesis of metal oxide nanoparticles has become increasingly vital. This method is more environmentally friendly and offers a faster reaction rate than conventional chemicals. Plant extracts contain a variety of active biomolecules that facilitate the stability and reduction of nanoparticles. NPs with smaller dimensions have an increased surface area, which modifies their magnetic, chemical, and electronic properties, as well as the characteristics of metal oxide nanoparticles. Magnetic resonance imaging techniques and magnetic storage devices, for instance, have utilised magnetite-type Zinc-doped Copper oxide nanoparticles as a contrast agent. The superparamagnetic nanoparticle possesses a diameter of 12 nm. Consequently, nanoparticles of the appropriate size exhibit the anticipated magnetic, electronic, and chemical properties.[14] Zinc-doped Copper oxide nanoparticles find applications across various domains, including medicine, biotechnology, environmental protection, and photocatalysis. Numerous methods are employed to synthesise these nanoparticles, such as thermal decomposition, Sono chemical reactions, and hydrothermal processes.[15-17] Although these methods often require specialised equipment and incur high costs, they typically yield low outputs. Additionally, the processes involve the use of toxic, corrosive, and flammable chemicals, and the waste solvents and reducing agents generated during synthesis pose risks to

http://doi.org/10.31788/RJC.2026.1919441

both environmental and human health. By employing natural precursors like plants, bacteria, seeds, and algae, the drawbacks associated with traditional methods can be mitigated through sustainable and eco-friendly approaches. Secondary metabolites derived from natural initiators serve as stabilising and reducing agents in green synthesis.[18] The characteristics of nanoparticles are influenced by the type and part (stem, cell, leaf, seed, etc.) of the natural precursors, along with the extraction methods and conditions. The purification process also affects the quantity and quality of the nanoparticles. In summary, the experimental conditions significantly influence the properties of the synthesised nanoparticles, and various nanoparticles have been produced from different biological sources.[18] *Ficus carica* is a diploid species that belongs to the Moraceae family, which includes more than 1400 species organised into 37 genera. The fruits and leaves of *Ficus carica* have been part of human consumption for centuries; however, the pharmacological properties of the tree's different parts have only recently been the subject of study. In *Ficus carica*, secondary metabolites like flavonoids, phenolic compounds, phytosterols, and fatty acids have been found to demonstrate antiviral, antibacterial, antifungal, hypoglycemic, and antimicrobial properties.[19] Photocatalysis is defined as the process that accelerates a photoreaction in the presence of a catalyst. It is imperative to eliminate or destroy chemicals that are pollutants in wastewater from industrial or domestic sources before they are released into the environment. Such pollutants may also be present in ground and surface water, which must be treated to adhere to drinking water standards. The technique of photocatalysis is gaining traction as a viable method for the degradation of pollutants. In the past two decades, advancements have been made in the use of colloidal semiconductors and the introduction of catalysts to enhance specific redox processes on semiconductor surfaces. Rhodamine B is classified as an amphoteric dye, although it is generally considered basic due to its overall positive charge. This dye is highly soluble in water and is part of the xanthene group. It is a reddish violet powder sold under the trade name D&C Red No. 19. Rhodamine B is toxic if ingested by humans or animals, leading to irritation of the skin, eyes, and respiratory tract, and it is extensively used in various industrial processes, including paper dyeing and dye laser production. The maximum absorbance (λmax) of Rhodamine B is approximately 550–555nm.[20] The leaf extracts were used to make Zinc doped Copper Oxide NPs, which were then characterised by using EDX, Transmission electron microscopy, UV-visible spectroscopy, Fourier transform infrared spectroscopy (FT-IR) and X-ray diffraction (XRD). These nanoparticles' antioxidant activity was also tested.

EXPERMENTAL

Apparatus and Materials

A Shimadzu UV-1800 spectrophotometer was used to analyse UV-Vis spectra, and a Shimadzu IR-Affinity spectrophotometer was used to record FT-IR spectra. A Scanning electron microscope LEO-EVO 40 equipped with an EDX Bruker-125 eV was used to examine the elemental composition, surface morphology, and size of Zinc doped Copper Oxide NPs. On a Rikagu RINT-2000, XRD patterns were measured. In addition, ultra-pure water was used in all of the studies. The following substances were used: 0.1 M Copper acetate and 0.1 M Zinc acetate (97.0) per cent, and sodium hydroxide (99.5 per cent, NaOH). All of the solutions were made with ultrapure water. Before using, all the glassware was rinsed with distilled water, and it was dried in a hot-air oven.

Preparation of Extract

Fresh Ficus carica leaves were gathered, thoroughly washed twice with tap water and deionised water, and subsequently dried for two days at 70 °C in a laboratory oven. A laboratory grinder was employed to pulverise the dried leaves into a fine powder. In a 500 mL flat-bottom flask, 10 g of the finely divided leaf particles were dissolved in 200 mL of deionised water. This mixture was heated and stirred for one hour in a water bath at 80 °C. The resulting liquid leaf extract was then filtered using filter paper and stored in an amber bottle in the refrigerator.

Green Synthesis of Zinc-Doped Copper Oxide Nanoparticles

0.1M Copper acetate and 0.1 M Zinc acetate were dissolved in 100 ml of deionised water. This mixture was then poured into a bottom flask and heated to 70 ^{o}C while using a mechanical stirrer. The plant extract was added in drops to the stirring solution, reaching a total volume of 40 mL. The pH of the

mixture was adjusted to a basic state (pH 9) by adding a few drops of 0.1 M NaOH. The mixture was stirred for one hour. To eliminate any unreacted salts or metabolites, the final product was centrifuged, washed several times with ultrapure water, and subsequently dried in an oven at 80 ^{o}C for one day.

Determination of Antioxidant Activity

Two unique tests were utilised to ascertain the antioxidative activity of the final product in nanoparticle form: ORAC (oxygen radical absorption capacity) and DPPH free radical scavenging activity. A specific measurable amount of the nanoparticle was incorporated into a DPPH (1,1-diphenyl-2-picrylhydrazyl) radical solution prepared in methanol, and the mixture was kept in the dark for 30 minutes to evaluate its radical scavenging activity. The number of free radicals in the tube containing nanoparticles (Abs sample) was compared to the tube containing no nanoparticles (Abs blank) by measuring the absorbance at 517 nm at the end of this time period. The same experiment was performed with ascorbic acid, a widely recognised antioxidant. The following equation in percentage was applied to calculate the scavenging activities of both ascorbic acid and nanoparticles. Consequently, the ascorbic acid equivalent (mg AAE/g sample) was employed to express the DPPH free radical scavenging efficiency of 1 gram of nanoparticles. (A blank - Asample) /A blank x 100 = scavenging activity (percentage). Moreover, by repeating the experiment with various quantities of nanoparticles, the number of nanoparticles needed to neutralise 50% of the radicals in the environment was determined as SC50. A spectrophotometric method using pyrogallol red (PGR) illustrated the ORAC of nanoparticles exhibiting antioxidant activity. In this method, 12.6 M PGR was combined with 1.0 mM AAPH (2,2'Azo-bis (2-amidinopropane) dihydrochloride) as a source of peroxyl radicals in a phosphate buffer (pH 7.4, 75mM) in the presence of the sample, and the absorbance was calculated in relation to the substance of the tube blank without the sample after incubation at 37°C. The ORAC value for the tested sample was assessed as Trolox equivalent (mg TXE/ g sample) using the graph derived from repeated methodology in the presence of various concentrations of Trolox, which functions as a reference antioxidant. The ORAC method, which was the second antioxidant activity evaluation method applied, illustrates the number of free radicals that can be neutralised by the sample. Based on the results, 1 g of nanoparticles demonstrates an oxygen radical scavenging activity equivalent to 7.360 mg of Trolox.

Photocatalytic Activity

The investigation into the photocatalytic activity of the synthesised nanoparticles involved measuring the degradation of RhB in an aqueous solution (10 μg/L) under visible light irradiation. Prior to the irradiation, the solution was stirred in the dark for 30 minutes to reach adsorption equilibrium. During the visible light irradiation, the reaction solution was sampled at regular intervals using a Millipore syringe (0.45 μm) and analysed for RhB dye concentration using UV-Visible spectrophotometry at 553 nm (λmax). Furthermore, a blank test was conducted for the aqueous solution of RhB without the photocatalyst under visible light irradiation; this was to perform the photolysis of RhB and assess the efficiency.

RESULTS AND DISCUSSION

In the realm of composition and size analysis, conducting a morphological screening of synthesised nanoparticles is vital, and SEM analysis was utilised in this research. Figure-1(a) illustrates SEM images of the synthesised product at a magnification of 100K, whereas Fig.-1(b) illustrates SEM images of the synthesised product at a magnification of 60K. The particle size was observed to range from 40 to 60 nanometers. The figures reveal that the nanoparticles tend to cluster and adopt multiple forms. The agglomeration of nanoparticles could result from the building blocks of various bioactive reducing agents, the diminished capping ability of leaf extract, and the hydrogen bonding present in bioactive molecules.

X-ray diffraction patterns of Zn-CuO at 31^0, 35^0, 37^0, 42^0, 57^0, and 63^0correspond to the (100), (101), (102), (110), (103), (200), and (112) planes, respectively. These crystalline reflection data exhibit excellent agreement with the standard JCPDS 36-1451. The incorporation of *Ficus carica* extract in the doping process of Zn-CuO nanoparticles is an innovative approach that leverages the phytochemicals present in the plant material. This method aligns with the green synthesis paradigm, which emphasises environmentally friendly techniques. The observed peak at 20° in the X-ray diffraction (XRD) pattern suggests a significant interaction between the *Ficus carica* phytochemicals and the Zn-CuO matrix.

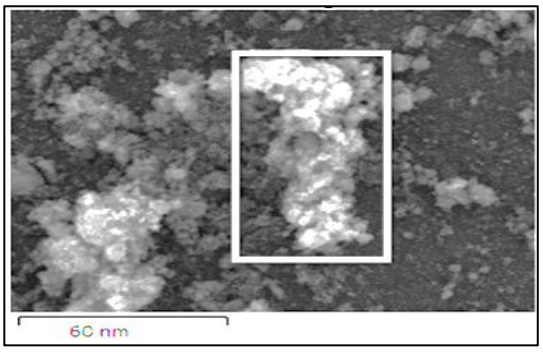


Fig.-1a: SEM analysis of *Ficus carica* Leaf Extract of Zinc-doped Copper Oxide NPs

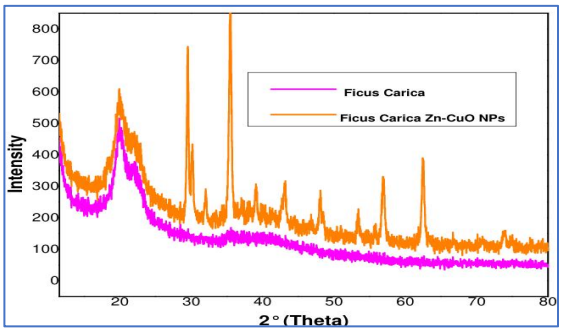
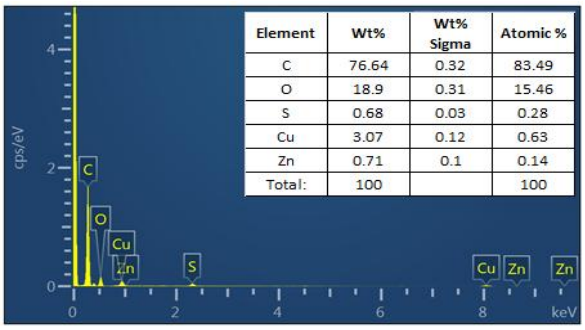


Fig.-1b: XRD Analysis of *Ficus carica* Leaf Extract Zinc Doped Copper Oxide NPs



Element	Wt%	Wt% Sigma	Atomic %
C	76.64	0.32	83.49
O	18.9	0.31	15.46
S	0.68	0.03	0.28
Cu	3.07	0.12	0.63
Zn	0.71	0.1	0.14
Total:	100		100

Fig.-1c: EDX Analysis of *Ficus carica* Leaf Extract Zinc Doped Copper Oxide NPs

Such interactions can potentially alter the structural and optical properties of the nanoparticles, as seen in similar studies where doping ZnO with Cu resulted in a red shift in the energy band gap and improved photocatalytic activities. The 100% doping of Zn-CuO with *Ficus carica* could lead to the development of nanoparticles with unique characteristics, possibly enhancing their applicability in various fields such as antibacterial agents or photocatalysts. It's important to further investigate the exact nature of these changes and their implications on the performance of the doped nanoparticles. EDX analysis was used to determine the elemental composition of Zn-CuO nanoparticles, confirming the presence of copper as a major metallic element [Fig.-1(d)]. The presence of Copper, Zinc, Oxide and other elements was determined using the EDX spectrum. The weight percentage of Cu (3.07 per cent) and Zinc was determined using EDX (0.71%). 18.9% of oxide and 77.32% of other elements (carbon and sulfur). Transmission Electron Microscopy (TEM) has been useful in determining the structure of zinc and copper oxide nanoparticles. Recent studies have used TEM to show *Ficus carica* leaf extract Zinc zinc-doped Copper oxide NPs. NPs have a spherical shape with an average diameter of 20 nm, as shown in Fig.-2a. These findings are critical because the shape and size of NPs have a significant impact on their properties and potential applications, such as antioxidant agents. FTIR analysis confirmed the surface functional groups and the formation of the ZnO-CuO nanocomposite, as shown in Fig.-2b. The FTIR spectrum of *Ficus carica* leave extract extract includes peaks at 3186, 2882, 2884, 1590, 1415, 11151020, and 950

cm^{-1}. The strong absorption bands at 3186 and 2882 cm^{-1} correspond to the bending vibrations of C-H stretching groups in alkynes and H-C-H alkanes. The bands at 2884 and 1590 cm^{-1} correspond to the H-C-H and N-H bending groups of amides, respectively. Furthermore, the peaks at 1415and 1115 cm^{-1} correspond to the C-C=C asymmetric stretch group in aromatic rings and the aliphatic group in ethers. The band at 1020 cm^{-1} is assigned to the C=N stretching vibration of aliphatic amines.

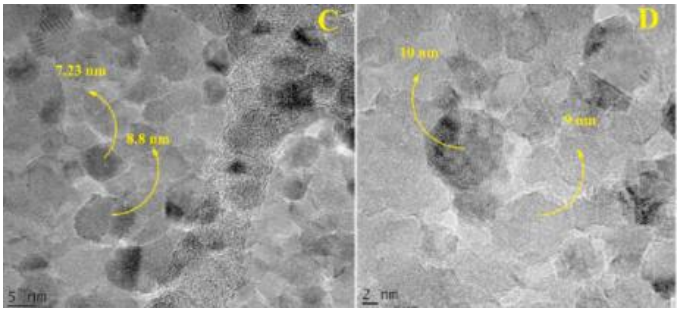


Fig.-2a: TEM Analysis of *Ficus carica* Leaf Extract Zinc Doped Copper Oxide NPs at different magnifications

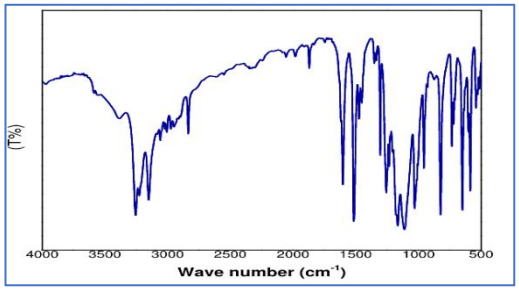


Fig.-2b: IR Spectrum of *Ficus carica* Leaf Extract Zinc-Doped Copper Oxide NPs

Antioxidant Activity

The antioxidant efficacy of the synthesised nanoparticles was established through two different approaches, leading to the conclusion that they possess exceptional antioxidant capabilities. The results derived from the DPPH test can be employed to measure the product's ability to capture free radicals. As per the DPPH test results, 1 gram of nanoparticles has antioxidant activity equivalent to 5.14 mg of ascorbic acid. Furthermore, it was found that at a concentration of 12.118 mg/mL, the nanoparticles have an antioxidant capacity that can neutralise half of the DPPH radicals in the environment. In other words, the SC50 value determined for the nanoparticles as a result of the DPPH test is 12.118 mg/mL. The DPPH radical scavenging efficiency of three different Zn-CuO nanoparticles synthesised through green methods from palm leaves ranged from 2 to 26.4 mg/mL. Fig.-2a) shows the TEM analysis of the synthesised Zinc-doped Copper oxide Nanoparticles.

Effect of Photo Catalyst Dosage

The purpose of the experiment was to analyse the effect of catalyst dosage on the degradation of RhB and to determine the optimal catalyst loading by varying the Zn-CuO nanoparticles from 0.05 to 0.4 g in 100 mL of RhB solution at a concentration of 10 µg/mL. The degradation improves with increasing catalyst loading up to 0.2 g, as the number of absorbed photons and the amount of dye molecules adsorbed increase in relation to the number of catalyst molecules until the active surface becomes constant, as presented in Table-1.

Once a specific quantity of catalyst molecules is reached, the available dye molecules become inadequate for further adsorption by additional catalyst molecules. Consequently, the extra catalyst powder does not enhance photocatalytic activity significantly; instead, it raises the turbidity of the solution, which disrupts the penetration of light transmission. Additionally, it was noted that an activated molecule may lose its activity upon colliding with a ground-state molecule while being shielded by ZnO. Figure 3 illustrates the impact of catalyst dosage.

Table-1: Effect of Catalyst Dosage on Degradation of Rhodamine B, Zn-CuO Nanoparticles, Rh B 10 µg/mL, pH=7.0

Time (Min)	% of degradation of Rhodamine B by Zn-CuO nanoparticles				
	0.05g	0.1g	0.2g	0.3g	0.04g
10	26.21	42.51	58.01	52	40.12
20	42.15	58.96	75.63	72.36	51.23
30	63.87	70.23	95.23	90.23	62.31
40	72.23	85.41	100.00	94.92	73.56
50	87.25	94.52		100.00	83.69
60	92.36	100.00			93.17
70	98.74				100.00
80	100.00				

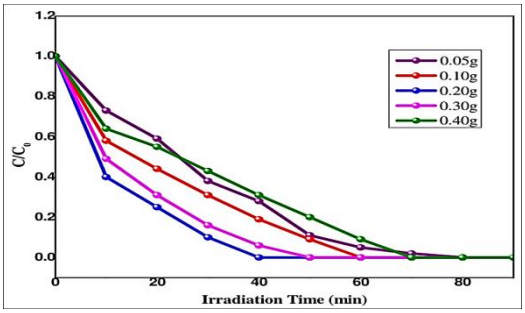


Fig.-3: Effect of Catalyst Dosage on the Degradation of RhB

CONCLUSION

The implementation of green synthesis strategies to produce eco-friendly and sustainable nanoparticles is quite promising. It is assumed that the favourable developments in nanoparticle research will be assessed. Future research will be driven by the synthesis of nanoparticles from low-cost and simple starting materials, along with the unique attributes of each synthesised product. In this study, Zn-CuO nanoparticles were synthesised and characterised from dried *Ficus carica* leaves, and their antioxidant activity was evaluated. Despite the challenge of achieving uniform product synthesis in this research, the recorded activity is remarkable. The researchers will continue to synthesise nanoparticles using various metal precursors obtained from natural products in future studies. Due to their antioxidant properties, green-synthesised Zinc-doped Copper oxide Nanoparticles should be further investigated in advanced studies as potential candidates for a variety of biomedical applications. The absorption data indicated that Zn-CuO nanoparticles increase the wavelength of Zn absorption (red shift), which enhances the photocatalytic degradation of RhB under visible light. The increased adsorption of RhB on the catalyst surface and the decrease in particle size resulting from Zn & Cu codoping are believed to be the reasons for the catalysts' high activity compared to undoped CuO.

AKNOWLEDGEMENTS

The authors would like to extend their heartfelt thanks to the Department of Chemistry at Mahatma Gandhi University, Nalgonda, Telangana - 508 254, which has been instrumental in the successful completion of this research work.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

The present work is related to *SDG-3: Good Health and Well-being*. All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

V. Sridhar https://orcid.org/0000-0001-6089-2336
Tentu Nageswara Rao http://orchid.org/0000-0001-7623-3343
Y. Prashanthi https://orcid.org/0009-0004-5397-050X

Cite this article as: V. Sridhar *et al.*, *Rasayan J. Chem.*, 19(1), 476-482(2026), https://doi.org/10.31788/RJC.2026.1919441.

REFERENCES

1. M. C. David, M. Ebrahim and V. C. Ada, *Journal of Physics: Materials,* **3**, 034005(2020), https://doi 10.1088/2515-7639/ab8186
2. V. N. Kalpana and R. V. Devi, *Bioinorganic Chemistry and Applications,* **2018**, 569758(2018), https://doi: 10.1155/2018/3569758
3. H. A. Bilal, S. Muzamil and S. H. Syed, *Nanomaterials,* **9**, 120(2019), https://doi.org/10.1016/j.ijbiomac.2018.09.025
4. A. Muthuvinothini and S. Stella, *Process Biochemistry*, **77,** 48(2019), https://doi.org/10.1016/j.procbio.2018.12.001
5. G. Yanli, X. Dan, R. Dan, Z. Kaifang and W. Xiyu, *Food Science and Food Safety*, **126**, 109297(2020), https://doi.org/10.1016/j.lwt.2020.109297
6. M. Nilavukkarasi, S. Vijayakumar, and S. Prathipkumar, *Materials Science for Energy Technologies*, **3**, 335(2020), https://doi.org/10.1016/j.mset.2019.12.004
7. A. Waseem and K. Divya, *Journal of King Saud University Science*, **32**, 2358(2020), https://doi.org/10.1016/j.jksus.2020.03.014
8. X. Zheng, W. Yuhui, S. Ling, C. Arunachalam, A. A. Sulaiman and F. Liwei, *Journal of King Saud University-Science,* **32,** 1865(2020), https://doi.org/10.1016/j.jksus.2020.01.023
9. E. T. Bekele, B. A. Gonfa, O. A. Zelekew, H.H. Belay and F. K. Sabir, *Journal of Nanomaterials*, **2020**, 2817037(2020), https://doi.org/10.1155/2020/2817037
10. S. Vijayakumar, B. Vaseeharan, B. Malaikozhundan and M. Shobiya, *Biomedicine & Pharmacotherapy,* **84**, 1213(2016), https://doi.org/10.1016/j.biopha.2016.10.038
11. M. D. Mauricio, S. Guerra-Ojeda and P. Marchio, *Oxidative Medicine and Cellular Longevity*, **2018**, 6231482(2018), https://doi.org/10.1155/2018/6231482
12. M. Seyyed, H. M. Tabrizi and E. Behrouz and J. Vahid, *Journal of Alloys and Compounds,* **821**, 153519 (2020), https://doi.org/10.1016/j.jallcom.2019.153519
13. N. I. Rasli, H. Basri and Z. Harun, *Heliyon*, **6**, e03156(2020), https://doi.org/10.1016/j.heliyon.2020.e03156
14. Üstün, Elvan, Sena Ceren Önbaş, Sakine Kübra Çelik and Melek Çol Ayvaz, *Biointerface Research in Appllied Chemistry,* **12,** 2108(2021), https://doi.org/10.33263/BRIAC122.21082116
15. S.Dhivya, S.I.Hussain, SJ.Sheela and S. Kalaiselvam, *Thermochimica Acta,* **671**, 70(2019), https://doi.org/10.1016/j.tca.2018.11.010
16. T. Dutta, T. Kim, K.Vellingiri. and K. Kumar, *Chemical Engineering Journal,* **62,** 364(2019), https://doi.org/10.1016/j.cej.2019.01.049
17. S. Narayanasarma and B.T. Kuzhiveli, *Asia-Pacific Journal of Chemical Engineering*, **15**, 2551(2020), http://dx.doi.org/10.1002/apj.2551
18. P. Uday Prakash, Y. Prashanthi1, T.B. Patrudu and Tentu Nageswara Rao, *Rasayan Journal of Chemistry*, 15 (4), 2620(2022), http://doi.org/10.31788/RJC.2022.1548030
19. Nancy Willian, Syukri, Zulhadjri, Arniati Labanni and Syukri Arief, *Rasayan Journal of Chemistry*, **13(3)**,1478(2020), http://dx.doi.org/10.31788/ RJC.2020.1335760
20. A. Waris, M. Din, A. Ali and A.U. Khan, *Inorganic Chemistry Communications*, **123**, 142(2020), https://doi.org/10.1016/j.inoche.2020.108369

[RJC-9441/2025]