RJC

RASĀYAN *J. Chem.*
Vol. 16 | No. 3 |1245-1253| July - September | 2023
ISSN: 0974-1496 | e-ISSN: 0976-0083 | CODEN: RJCABP
http://www.rasayanjournal.com
http://www.rasayanjournal.co.in

SYNTHESIS OF ZINC OXIDE NANORODS USING *Ficus benghalensis* AERIAL ROOT EXTRACT AND ITS ENHANCED ANTI-INFLAMMATORY AND ANTIBACTERIAL ACTIVITIES AGAINST DENTAL BACTERIA

V. Nandhakumar[1], J. Princess Gracia[1,✉], J. Prince Richard[2], N. Balasubramanian[3] and G. Suganya[1]

[1]Department of Chemistry, A.V.V.M. Sri Pushpam College (Affiliated to Bharathidasan University, Tiruchirappalli – 620024), Poondi, Thanjavur-613503, Tamilnadu, India

[2]Department of Science and Humanities, E.G.S. Pillay Engineering College, Nagapattinam-611002, Tamilnadu, India

[3]Department of Chemistry, SRM Institute of Science and Technology, Tiruchirappalli-621105, Tamilnadu, India

✉ Corresponding Author: princess.pyr@gmail.com

ABSTRACT

High-purity Zinc Oxide and *Ficus benghalensis* – Zinc Oxide Nanorods were developed by hydrothermal method. The physio-chemical characteristics of the Nanorods were investigated. X-ray Diffraction spectrum confirms the formation of well crystalline nanorods along (101) orientation. The particle size of as-synthesized Nano rods was noticed to be lesser than the chemically synthesized Zinc Oxide nanorods. The PL spectrum shows a broad red emission peak and a sharp blue emission peak. The width of the energy gap of nanorods is lesser than the chemically synthesized ones. The functional groups of the Nanorods were determined by Fourier Transformation Infrared analysis. Scanning Electron Microscope-Energy Dispersive X-ray analysis micrograph reveals the morphology of the nanorods and elements present. The antibacterial and anti-inflammatory efficiency of the Nanorods were evaluated by the Agar well diffusion method against some multi-drug safe oral microbes and the Bovine serum albumin (BSA) denaturation method.

Keywords: ZnO Nanorods, Dental Bacteria, *Ficus benghalensis* Root, Microstructural Parameters, Photoluminescence, Antibacterial, Anti-inflammatory.

RASĀYAN *J. Chem.*, Vol. 16, No. 3, 2023

INTRODUCTION

The branch of Nanoscience is quite possibly the best area to explore in the present day in view of multidrug obstruction. Since the 1980s, the investigation of nanoparticles (NPs) has been of critical significance because of their enhanced properties, including optical, electronic, and attractive applications; and all the more as of late because of their application in medication, similar to their utilization as differentiation components in attractive reverberation imaging studies, and for the therapy of malignant growth by hyperthermia. Synthesis of inorganic metal oxide NPs utilizing natural things has been of incredible interest because of their uncommon optical, synthetic, photo, electrochemical, and electronic properties. Zinc Oxide (ZnO) NPs enjoy an incredible benefit in their application as catalysts because of their enormous surface region and high catalytic activity. The metal nanoparticles can be created utilizing different compounds and actual courses like chemical reduction, electrochemical methods, and radiation, however, there is a developing need to create an eco-accommodating and size-control approach for the synthesis of metal nanoparticles. However, in modern days, plant extract has been utilized as stabilizing agent for the blend of NPs which could be profitable over microbial amalgamation since there is no need for the explained course of refined and keeping up with the phone. *Ficus benghalensis* (Indian Banyan tree) has incredible restorative worth and has plentiful phytoconstituents including ketones, flavonols, flavonoids, terpenoids, etc.[1-12] Dental caries is an issue because of oral biofilm and also dental microorganisms. Dental caries is nothing but tooth rot brought

http://doi.org/10.31788/RJC.2023.1638141

through various microbes. *Ficus benghalensis* aerial root extract was utilized for the greenway synthesis of Ag-Nano particles with various particle sizes however no reports for its use in the green synthesis of ZnO nanorods have been found, likewise, this plant species contains an incredible variety of natural mixtures that favor the synthesis of nanorods. Keeping in view the synthetic strategies of biogenic ZnO nanorods and the importance of *Ficus benghalensis*, this study aimed to synthesize *Ficus benghalensis* aerial root-mediated zinc oxide nanorods assisted with hydrothermal. The antibacterial capability of ZnO nanorods against multi-drug safe *Streptococcus mutans, Staphylococcus aureus, Treponema denticola, Porphyromonas gingivalis, Lacto bacillus* and anti-inflammatory activity were examined. The circumstances were improved utilizing a measurable method.

EXPERIMENTAL

Preparation of ZnO Nano Rods by Hydrothermal Technique

The ZnO Nanorods were tailored using zinc chloride ($ZnCl_2$) precursor. In this method 0.1 M solution of zinc chloride is stirred for 30 minutes at 60° C. 2 M solution of sodium hydroxide is added with constant stirring. The solution is now transferred to a 100 ml autoclave and maintained at 90°C for 15 minutes. It is filtered, dried, and kept in that muffle furnace at 250° C for about 3 hours. The powdered form of ZnO Nanorods was obtained. It is named ZnO.

Preparation of ZnO Nano-Particles Utilizing *Ficus Benghalensis* Aerial Root Extract and By Hydrothermal Technique

The aerial roots of *Ficus benghalensis* were collected, washed, and sun-dried. They were cut into small pieces and made into fine powder. The dry powder of *Ficus benghalensis* aerial root was stored in an airtight container. 20 g of powder is dissolved in 200 ml of deionized water and maintained at ambient temperature for 2 hours. The solution is then stirred for 2 hours at 40°C with a speed of 50 rpm. The extract is filtered and refrigerated. 0.1 M solution of zinc chloride is stirred for 30 minutes at 60° C. 2 M solution of sodium hydroxide is added with constant stirring. To this solution, 10 ml of aerial root extract is added and stirred well. The solution is now transferred to a 100 ml autoclave and maintained at 90° C. After 15 minutes, it is filtered and dried. This dried mass is further maintained at 250° C in a muffle furnace for 3 hours. Thus obtained ZnO Nanorods were designated as FB/ZnO.

Antibacterial Test

The antibacterial effect of ZnO and FB/ZnO Nanorods was assessed using Agar well diffusion method. Roughly 10^7 CFU ml^{-1} bacterial strains were cultivated with 1 ml of agar medium in a petri dish for 24 hours. Furthermore, wells ranging between 6–7 mm in diameter were injected with an aseptic stopper, and the nanoparticles were added. Then the dishes were nurtured at 37°C for about 24 hours. The antibacterial efficacy was evaluated by determining the size of the zone of inhibition (ZOI) developed (mm) in the well. The negative control used during the evaluation of antibacterial activity was 0.85% of NaCl.

Anti-Inflammatory Assay

The as-synthesized nanoparticles were evaluated for their anti-inflammatory efficacy through the BSA denaturation method. The test samples and the commercial standard drug Diclofenac Sodium were dissolved in 1 ml of 2.5% Dimethyl formamide and watered down using 0.2 Molarity phosphate buffer to maintain pH around 7.0. Test solution (1 ml) containing different concentrations such as 15, 30, 60, 120, and 240 µg/ml of nanoparticles were kept in incubation at 27°C in a water bath for 10 minutes. The opaqueness was identified at 660 nm spectrophotometrically. Percentage inhibition of denaturation was calculated.

$$Percentage\ Inhibition = \frac{Abs\ Control - Abs\ Sample}{Abs\ Control} x100$$

Characterization Techniques

The phase and structure of the ZnO and FB/ZnO Nanorods were analyzed using SHIMADZU-XRD 6000 analyzer. The morphological study was carried out using JSM-IT700 SEM. The UV-Vis absorption spectrum was done by using SHIMADZU-UV 1800 UV-Vis spectrophotometer. The functional groups were identified using Fourier Transformation Infra-Red spectra taken from Perkin-Elmer Spectrum RXI.

A fluorescence spectrophotometer (VARIAN) is used to record the PL spectrum of the sample at ambiance temperature at the excitation wavelength having 300 nm.

RESULTS AND DISCUSSION

Structural Analysis

X-Ray diffraction spectra of ZnO and FB/ZnO Nanorods were shown in Fig.-1. The strong peaks were observed at 2θ values of 31.21°, 34.65°, 36.22°, 47.28°, 56.41°, 64.17°, 68.14°, 68.96°, 69.24°, and 36.28° attributed to the (100), (002) (101), (103), (200), (112) and (201) planes. It was concluded that the samples have a wurtzite structure in relation to JCPDS Card No: 36-1451. The crystal size was calculated from the angle between the transmitted beam and the reflected beam and full width at half maximum of the (h k l) peaks by using Debye-Scherrer's equation.[12-15]

$$D = \frac{0.9\,\lambda}{\beta \cos\theta}$$

The results were correlated in Table-1. The crystal size of FB/ZnO and Nanorods were found to be lower than that of the ZnO Nanorods. The parameters like microstrain (ε) and dislocation density (δ) were determined from the following relations were also given in Table-1.

$$\varepsilon = \frac{\beta cos\theta}{4}$$

$$\delta = \frac{1}{D^2}$$

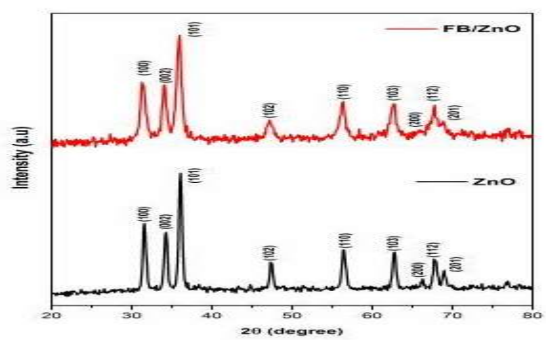

Fig.-1: XRD Spectrum of ZnO and FB/ZnO Nanorods

Table-1: Structural Parameters of ZnO and FB/ZnO Nanorods

Sample	Crystallite size D (nm)	Dislocation density δ ($\times 10^{14}$) lines/m^2	Micro strain ε
ZnO	16.53	36.5884	0.00219
FB/ZnO	10.52	90.3371	0.00344

Optical Studies

UV–Vis spectroscopy technique has been utilized to know the optical properties of the prepared Nanorods. Figure-2 reveals the absorption peaks of ZnO and FB/ZnO Nanorods. A strong absorption peak was found at 380nm in both samples which inferred ZnO particles. The optical band gap width was determined by the equation given below:

$$(\alpha h\nu) = A(h\nu - E_g)^n$$

Where, A is a constant, n = 2, ν - the incident radiation frequency, E_g - material band gap, and h - Planck's constant. Figure-3 gives the $(\alpha h\nu)^2$ vs. hν plot. The widths of energy gap values were determined from the Tangent lines which meet the hν axis. The obtained energy bandgap values are 3.29eV and 3.34eV for ZnO and FB/ZnO nanorods respectively. The increased bandgap of FB/ZnO nanorods is due to the reduced crystal size.[16,17]

Photoluminescence Studies

Figure-4 shows the Photoluminescence spectra of the samples at the wavelength of 325 nm. This is in between the range of 350nm and 950 nm. ZnO Nanorods show two emission peaks: A sharp blue peak at

360 nm for UV emission and a broad peak at 520 nm for red emission. The red emission peak is generally attributed to trapping state emission.

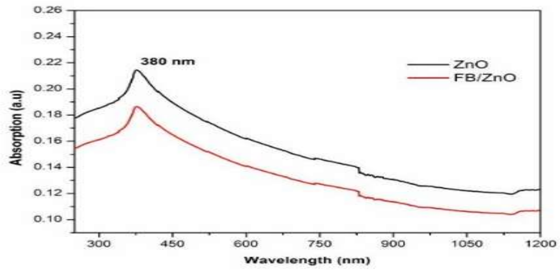

Fig.-2: Absorption Spectra of ZnO and FB/ZnO Nanorods

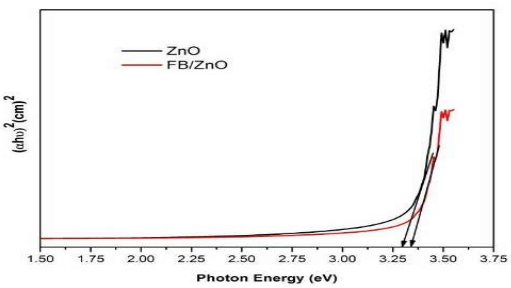

Fig.-3: Band Gap Energy Calculation Graph of ZnO and FB/ZnO Nanorods

This is because of the transition between the recombination of ionized oxygen vacancy and a photo-generated hole. The position of the spectrum relies on the interspace between the acceptor and the donor in a pair: the energy of the photon generated is inversely proportional to the interspace between the acceptor and donor pair.[18,19]

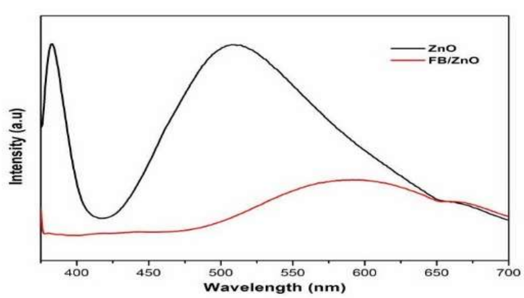

Fig.-4: PL Spectra of ZnO and FB/ZnO Nanorods

Morphological Study

Figure-5 (a) is the SEM image of ZnO Nanorods. The image confirmed the dispersed rod-shaped ZnO. Figure-5 (c) is the SEM image of FB/ZnO nanorods. This reveals that the Nanorods exhibit a more agglomerated structure with irregular morphology as compared to that of the ZnO nanorods. This is because the addition of *Ficus benghalensis* with ZnO diminishes the nucleation. Figure-5 (b) and (d) are the EDAX spectrum of ZnO nanorods and FB/ZnO nanorods respectively. It is clear from Fig.-5 (b) that the Nanorods have the elements Zinc and Oxygen only. No other peaks were obtained which confirms the purity of the material. However, in Fig.-5 (d), there are some traces of Carbon in addition to Zn and O which is mainly attributed to the addition of *Ficus benghalensis*.

Fourier Transformation Infrared Spectroscopy

Figure-6 is the Fourier Transform Infra-Red spectra of ZnO and FB/ZnO Nanorods. The most intense peak at 500-550 cm^{-1} is due to Zn-O stretching vibration. The hump nearer to 780-880 cm^{-1} belongs to the C-H loop bending vibration. The peak nearer to 1025 cm^{-1} confirms the C-O bond. The peaks present in the range 1350-1650 cm^{-1} are related to C-C and C-H bonds. The small peak near 2340 cm^{-1} reveals the C≡C in the skeleton. The absorption peaks ranging from 2850-2950 cm^{-1} are related to H-C=O bonding. It was proposed that, there were peak shift in green synthesized ZnO nanorods compared with chemically synthesized ZnO nanorods which showed the impact of *Ficus benghalensis* aerial root extract in nanorod synthesis process.[20,21]

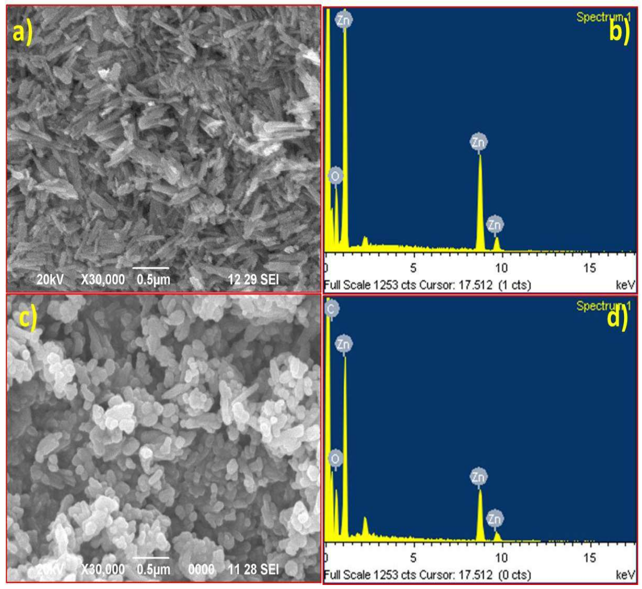

Fig.-5: (a) SEM Image of ZnO Nanorods, (b) EDAX Spectrum of ZnO Nanorods, (c) SEM Image of FB/ZnO Nanorods and (d) EDAX Spectrum of FB/ZnO Nanorods

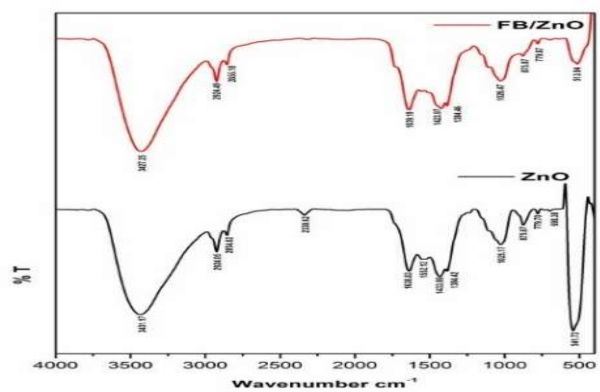

Fig.-6: FTIR Spectra of ZnO and FB/ZnO Nanorods

Antibacterial Assay

The antibacterial effect of ZnO Nanorods and FBZnO Nano rods was assessed using Agar well diffusion method against some significant oral microbes like *Streptococcus mutans, Staphylococcus aureus, Treponema denticola, Porphyromonas gingivalis* and *Lacto bacillus* for various nanorods concentration (15, 30, 60, 120 and 240 µl). Figure-7 and Fig.-8 show the zone of inhibition produced by ZnO and FB/ZnO nanorods in various oral microbes. It has been inferred from the image that with an increase in nanorods concentration there is a significant increase in the zone of inhibition. Also, it has been found that FB/ZnO nanorods show a better zone of inhibition as compared to that of the chemically synthesized nanorods. The decreased particle size and the presence of flavonoids and phenolic compounds in *Ficus benghalensis* were majorly attributed to the increased antibacterial efficiency of FB/ZnO nanorods.[22-28] The results are tabulated in Table-2.

Anti-Inflammatory Activity

The efficiency of ZnO and FB/ZnO nanorods on anti-inflammatory was evaluated by the Bovine serum albumin denaturation method. The results are presented in Table-3. It has been found from the results that both ZnO and FBZnO nanorods show better anti-inflammatory efficiency than the standard anti-inflammatory agent Diclofenac sodium. Denaturation of proteins is a very much acknowledged instance of inflammation, so any phytoconstituent which has the capacity to safeguard the denaturation of protein could contribute fundamentally to inflammation. The structure and morphology of nanoparticles are significant determinants of the protein-restricting cycle. ZnO NPs surface properties influence the nature of proteins; some of the times suppress the denaturation of proteins. Adding a phytoconstituent with ZnO increases its anti-inflammatory activity. This is because the higher level of phenolic compounds present in *Ficus benghalensis* prevents the protein denaturation process.[29,30]

Table-2: Antibacterial Activities of ZnO and FB/ZnO Nanorods Against Multi-Drug Safe Bacterial Strains The Values are Expressed in Terms of (Mean ± Standard deviation)

Name of the Bacteria	Zone of inhibition (mm)									
	15µl		30µl		60µl		120µl		240µl	
	ZnO	FB/ZnO	ZnO	FB/ZnO	ZnO	FB/ZnO	ZnO	FB/ZnO	ZnO	FB/ZnO
Streptococcus Mutans	11.5±0.15	11.0±0.23	12.0±0.04	12.0±0.47	13.5±0.78	12.5±0.07	14.0±0.16	13.5±0.64	14.5±0.19	15.0±0.79
Staphylococcus Aureus	08.0±0.16	12.0±0.17	08.5±0.13	13.0±0.23	09.0±0.17	13.5±0.61	09.5±0.11	14.0±0.11	10.0±0.01	15.0±0.07
Treponema denticola	09.0±0.17	17.0±0.12	10.0±0.54	19.0±0.06	12.0±0.12	20.0±0.45	13.0±0.09	21.0±0.16	15.0±0.17	22.0±0.48
Porphyromonas Gingivalis	10.0±0.16	11.0±0.16	10.5±0.33	11.5±0.08	11.0±0.45	12.0±0.15	12.0±0.04	12.5±0.03	12.5±0.66	13.0±0.64
Lactobacillus	08.5±0.12	09.0±0.52	09.0±0.11	10.0±0.11	09.5±0.41	10.5±0.10	10.0±0.55	11.0±0.56	10.5±0.06	11.5±0.08

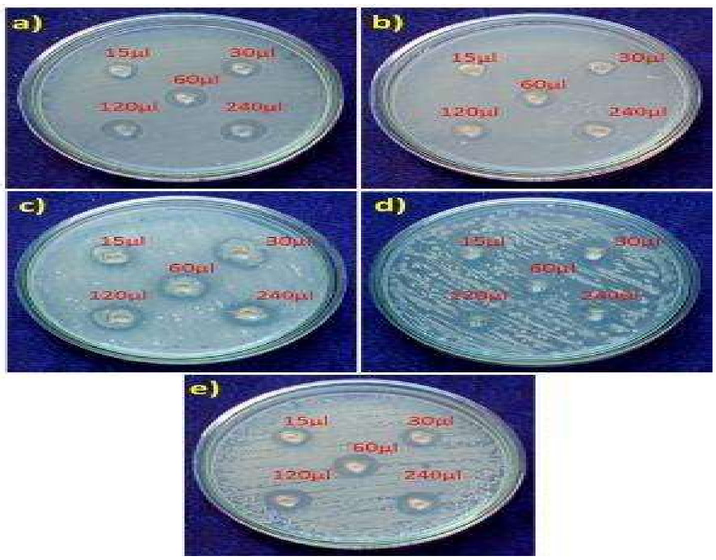

Fig.-7: Zone of Inhibition Produced by ZnO Nanorods

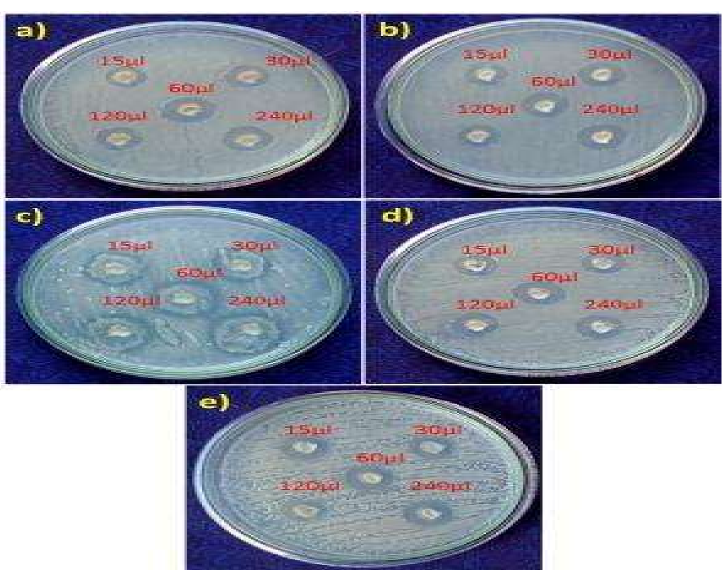

Fig.-8: Zone of Inhibition Produced by FB/ZnO Nanorods

Table-3: Anti-inflammatory Activities of standard Diclofenac Sodium, ZnO, and FB/ZnO Nanorods

Different concentrations (µg/ml)	Percentage Inhibition (%)		
	Standard (Diclofenac sodium)	Bovine serum albumin denaturation method	
		ZnO NPs	FB/ZnO NPs
15	15.04±0.45	22.80±0.04	31.08±0.22
30	26.91±0.14	27.12±0.67	41.83±0.62
60	29.47±0.16	31.45±0.31	53.57±0.91
120	47.19±0.22	51.84±0.86	75.95±0.24
240	75.17±0.16	87.44±0.81	93.87±0.58

The values are expressed in terms of (Mean ± Standard deviation)

CONCLUSION

In the present study, ZnO and FB/ZnO nanorods were prepared by a cost-effective hydrothermal technique. The structural, morphological, optical, and functional group analysis of the prepared Nanorods has been inspected with XRD, SEM-EDAX, UV, PL, and FTIR analysis. XRD spectrum authenticates the emergence of high-clarity hexagonal wurtzite-structured ZnO nanorods. FB/ZnO possess reduced particle size as bio-functional groups present in *Ficus benghalensis* acts as reducing agent in the synthesis process. The SEM image confirms the formation of well-indexed nanorods and the EDAX spectrum reveals the stoichiometric presence of Zinc and Oxygen. The bandgap of FB/ZnO nanorods is found to be lesser than that of the chemically synthesized ZnO nanorods. This is because of the reduced particle size of the FB/ZnO nanorods. The PL spectra show two peaks; a sharp blue peak at 360 nm for UV emission and a broad peak at 520 nm for red emission. The vibrational groups present in nanorods were studied using Fourier Transformation Infra-Red spectroscopy. Finally, the antibacterial and anti-inflammatory efficiency of ZnO and FB/ZnO nanorods were examined by the Agar well diffusion method against some multi-drug safe oral microbes and the Bovine serum albumin denaturation method. The FB/ZnO nanorods exhibit better antibacterial and anti-inflammatory properties than chemically synthesized ZnO nanorods because of the presence of higher-level phenolic compounds. It has been concluded from the results that the incorporation of phytoconstituent (*Ficus benghalensis*) into ZnO significantly enhances its antibacterial and anti-inflammatory efficiency. In the future, FB/ZnO nanorods can be an effective alternative for Zinc Oxide – Eugenol dental cement, which has been conventionally used for temporary dental carries filling.

ACKNOWLEDGMENTS

The authors are grateful to those who offered suggestions when they were writing this work.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

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. Nandhakumar http://orcid.org/0000-0003-2186-7239
J. Princess Gracia http://orcid.org/0000-0001-8744-4867
J. Prince Richard http://orcid.org/0000-0002-9783-0531
N. Balasubramanian http://orcid.org/0009-0008-7097-4130
G. Suganya http://orcid.org/0009-0009-6963-1111

REFERENCES

1. M. O. Kyene, E. K. Droepenu, F. Ayertey, G. N. Yeboah, M. A. Archer, D. Kumadoh, S. O. Mintah, P. K. Gordon, A. A. Appiah, *Scientific African*, **19**, e01452(2023), https://doi.org/10.1016/j.sciaf.2022.e01452

2. J.L. Lopez-Miranda, G.A. Molina, M.A. González-Reyna, B.L. España-Sánchez, R. Esparza, R.Silva, M. Estévez, *International Journal of Molecular Sciences*, **24(2)**, 1474(2023), https://doi.org/10.3390/ijms24021474
3. C. Pushpalatha, J. Suresh, V.S. Gayathri, S.V. Sowmya, D. Augustine, A. Alamoudi, B. Zidane, N.H. Mohammad Albar, S. Patil, *Frontiers in Bioengineering Biotechnology*, **10**, 917990(2022), https://doi.org/10.3389/fbioe.2022.917990
4. M. D. Barma, I. Muthupandiyan, S. R. Samuel, B. T. Amaechi, *Archives of Oral Biology*, **126**, 105132, (2021), https://doi.org/10.1016/j.archoralbio.2021.105132
5. H. Moradpoora, M. Safaei, H. R. Mozaffaric, R. Sharifid, M. M. Imanie, A. Golshahe and N. Bashardoust, *RSC Advances*, **11**, 21189(2021), https://doi.org/10.1039/D0RA10789A
6. B. A. Sevinç, L. Hanley, *Journal of Biomedical Materials Research Part B: Applied Biomaterials*, **94(1)**, 22(2010), https://doi.org/10.1002/jbm.b.31620
7. A. Balduit, A. Mangogna, C. Agostinis, G. Zito, F. Romano, G. Ricci, R. Bulla, *Nutrients*, **12(6)**, 1822(2020), https://doi.org/10.3390/nu12061822
8. P.C. Nagajyothi, S. J. Cha, I. J. Yang, T.V.M. Sreekanth, K. J. Kim, H. M. Shin, *Journal of Photochemistry and Photobiology B: Biology*, **146**, 10(2015), https://doi.org/10.1016/j.jphotobiol.2015.02.008
9. I.K. Punithavathy, J.P. Richard, S.J. Jeyakumar, M. Jothibas, P. Praveen, *Journal of Materials Science: Materials in Electronics*, **28**, 2494(2017), https://doi.org/10.1007/s10854-016-5823-4
10. B. Liu, H. C. Zeng, *Journal of the American Chemical Society*, **125(15)**, 4430(2003), https://doi.org/10.1021/ja0299452
11. P. K. Aspoukeh, A. A. Barzinjy, S. M. Hamad, *International Nano Letters*, **12**, 153(2022), https://doi.org/10.1007/s40089-021-00349-7
12. S. Laurent, C. J. Ramos, S. Denis 2018, *Royal Society Open Science,* http://doi.org/10.1098/rsos.180510
13. J.P. Richard, I.K. Punithavathy, S.J. Jeyakumar, M. Jothibas, P. Praveen, *Journal of Materials Science: Materials in Electronics,* **28**, 4025(2017), https://doi.org/10.1007/s10854-016-6016-x
14. P. K. Samanta, A. K. Bandyopadhyay, *Applied Nanoscience*, **2**, 111(2012), https://doi.org/10.1007/s13204-011-0038-8
15. R. Devaraj, K. Karthikeyan, K. Jeyasubramanian, *Applied Nanoscience*, **3**, 37(2013), https://doi.org/10.1007/s13204-012-0072-1
16. N. Kumar, A. Katiyar, R. K. Shukla, A. Srivastava, In the Proceedings of the International Conference on Optics and Electro-Optics, Dehradun, India, Part of the Springer Proceedings in Physics book Series (SPPHY,Volume 258), (2021), https://doi.org/10.1007/978-981-15-9259-1_15
17. M. Misra, P. Kapur, M. L. Singla, *Journal of Materials Science: Materials in Electronics*, **24**, 3940(2013), https://doi.org/10.1007/s10854-013-1343-7
18. D. Ying, Z. Yue, P. Xin-mei, C. Wen, *The Journal of Wuhan University of Technology-Material Science Edition*, **18**, 20(2003), https://doi.org/10.1007/BF02838449
19. S.S. Kurbanov, S. Z. Urolov, Z. S. Shaymardanov, H. D. Cho and T. W. Kang, *Semiconductors*, **52**, 897(2018), https://doi.org/10.1134/S1063782618070126
20. B. T. Naik, E. J. E. Packiyam, Amardeep, *International Journal of Current Research in Chemistry and Pharmaceutical Sciences*, **5(9)**, 13(2018), http://doi.org/10.22192/ijcrcps.2018.05.09.003
21. T. R. Patave and A.U. R. Siddiqui, *Journal of Pharmaceutical Research International*, **33(41A)**, 257(2021), https://doi.org/10.9734/jpri/2021/v33i41A32325
22. F. Mirhosseini, M. Amiri, A. Daneshkazemi, H. Zandi, Z. S. Javadi, *Frontiers in Dentistry*, **16(2)**, 105(2019), https://doi.org/10.18502/fid.v16i2.1361
23. M. Banoee, S. Seif, Z.E. Nazari, P. Jafari-Fesharaki, H.R. Shahverdi, A. Moballegh, K.M. Moghaddam, A.R. Shahverdi, *Journal of Biomedical Materials Research – Part B: Applied Biomaterials*, **93(2)**, 557(2010), https://doi.org/10.1002/jbm.b.31615
24. N. A. Jasim, F. A. Al-Gasha'a, M. F. Al-Marjani, A. H. Al-Rahal, H. A. Abid, N. A. Al-Kadhmi, M. Jakaria, A. M. Rheima, *Biocatalysis and Agricultural Biotechnology*, **29**, 101745(2020), https://doi.org/10.1016/j.bcab.2020.101745

25. M. A. Rauf, M. Owais, R. Rajpoot, F. Ahmad, N. Khan and S. Zubair, *RSC Advances*, **7**, 36361(2017), https://doi.org/10.1039/C7RA05040B
26. R. P. Allaker,(2012),The Use of Antimicrobial Nanoparticles to Control Oral Infections. In: Cioffi, N., Rai, M. (eds) Nano-Antimicrobials. Springer, Berlin, Heidelberg, pp 395-425, https://doi.org/10.1007/978-3-642-24428-5_14
27. T.M.T. Nguyen, P.W Wang, H.M. Hsu, F.Y. Cheng, D.B. Shieh, T.Y. Wong, H.J. Chang, *Materials Science and Engineering: C*, **97**, 116(2019), https://doi.org/10.1016/j.msec.2018.12.007
28. J. Wang, L. Du, Y. Fu, P. Jiang and X. Wang, *BMC Oral Health*, **19**, 84(2019), https://doi.org/10.1186/s12903-019-0780-y
29. H. Agarwal, V. Shanmugam, *Bioorganic Chemistry*, **94**, 103423(2020), https://doi.org/10.1016/j.bioorg.2019.103423.
30. S. Murthuza, B.K. Manjunatha, *Beni-Suef University Journal of Basic and Applied Sciences*, **7(4)**,719(2018), https://doi.org/10.1016/j.bjbas.2018.10.001

[RJC-8141/2022]