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ZnO Nanoparticles; synthesis, spectral characterization, and antibacterial activity - an ecofriendly approach

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Abstract

The synthesis of metal oxide nanoparticles with the use of plant extract is a promising alternative to the conventional chemical method. This is work aimed to synthesize Zinc Oxide nanoparticles using plant leaves extract of *Aegle marmelos*, and investigation of its antibacterial activity. *Aegle marmelos* leaves are of considerable interest and are a well-known compound because of its antioxidant, antibacterial, and antifungal activities, etc, In the present study focus is on the green synthesis of ZnO nanoparticles by potassium hydroxide, Zinc acetate, and bio components of leaves of *Aegle marmelos*. Further, the green synthesized ZnO nanoparticles were characterized by UV -Visible spectrophotometer (UV-Vis), X-ray diffraction analysis(XRD), Fourier transform infrared (FTIR), and Scanning electron microscope (SEM) techniques. This analysis confirms the formation of ZnO nanoparticles. The antibacterial activity of the ZnO nanoparticles was evaluated by testing against Gram-positive (S. aureus) bacteria. The antibacterial activity of the synthesized ZnO nanoparticles was found to be more effective against gram-positive bacteria (S. aureus).

Keywords: Green synthesis, ZnO nanoparticles, SEM, UV-Vis spectrometer, *Aegle marmelos*.

1. Introduction

Nanotechnology is one of the fastest-growing technologies, which will likely form the basis of technological and biotechnological innovations hence, it is considered to be the upcoming industrial revolution of the century [1]. Recently metal nanoparticles, carbon nanotubes, and metal oxide nanoparticles having antibacterial effects have been reported [2,3]. Nanoparticles have been used an chemical sensors, anticorrosive, antimicrobial agents, and in piezoelectric devices [4,6]. Zinc oxide nanoparticles are considered an an elite nanomaterial and are grouped with graphene, carbon, nanotubes, and gold due to their broad applications [7]. It has also been generally recognized as a safe material that is non-toxic, safe, and biocompatible [8,9].

Green Synthesis of ZnO nanoparticles and its Antibacterial activity.

such as optimal chemical stability, solubility, and adhesiveness. The reaction of salt and ligand has broadened the spectra of many biological and environmental research areas and plays a significant role in electronic devices, radiolabeling, medicinal applications, and contaminant detection. [14].

The biosynthesis of zinc oxide has reported the potential of plant extract as biological material for the synthesis of nanoparticles is yet to be fully explored. Therefore, the aim of this study was the green synthesis of zinc oxide nanoparticles using an extract of *Aegle marmelos* leaves and the evaluation of their antibacterial activity in the synthesis of nanomaterials. The use of biological components has always been a preferred choice for an environmentally friendly approach known as green synthesis. In addition to the environmental ecosystem benefits, green synthesis has been proven to be very useful method in controlling the desired nanoparticle's size and shape [15]. Various studies have suggested that plant extracts are a better candidate and more appropriate for large-scale green nanoparticle synthesis, owing to the high rate of synthesis as compare to bacteria, fungi, yiest based nanoparticles synthesis [16,17]. Nanoparticles are now considered as nanoantibiotics because of their antimicrobial activities [18]. Nanoparticles have been integrated into various industrial, health, food, chemical, and cosmetics industries of consumers which calls for a green and environment-friendly approach to their synthesis [19].

2. Material and Method

Collection and Preparation of Plant Material

Fresh leaves of *Aegle marmelos* were collected and thoroughly washed using tap and distilled water to remove the dust particle and sun-dried to remove the residual moisture the dried leaves were then ground into powder. The aqueous extracts of the sample were prepared by boiling 5gm of finely powdered leaves in 100 ml of double distilled water at 90^{0}C for one hour while stirring using a magnetic stirrer at 900rpm. The extract was then cooled to room temperature and filtered using Whatman No.1 filter paper and stored in a refrigerator at 4^{0}C for further experimental use [20].

Biosynthesis of Zinc Oxide Nanoparticles.

1:1 (50 ml *Aegle marmelos* extract and 50 ml of 0.1 M zinc acetate solution), 3:2 (60 ml *Aegle marmelos* extract and 40 ml of 0.1M zinc acetate solution) and 9:1 (90 ml *Aegle marmelos* extract and 10 ml of 0.1 M zinc acetate solution) ratios were stirred for half hour using magnetic stirrer, after that 10 ml of 0.1M sodium hydroxide (NaOH) solution was added dropwise stirrer for two hours at 800rpm which resulted into light yellow precipitate formation the precipitate was then filtered using a glass filter and washed repeatedly with distilled water followed by ethanol to remove the impurities and oven dried at 80^{0}C for two hours. The obtained dried light yellow color powders were mashed using a mortar and pestle and made ready for further characterization.

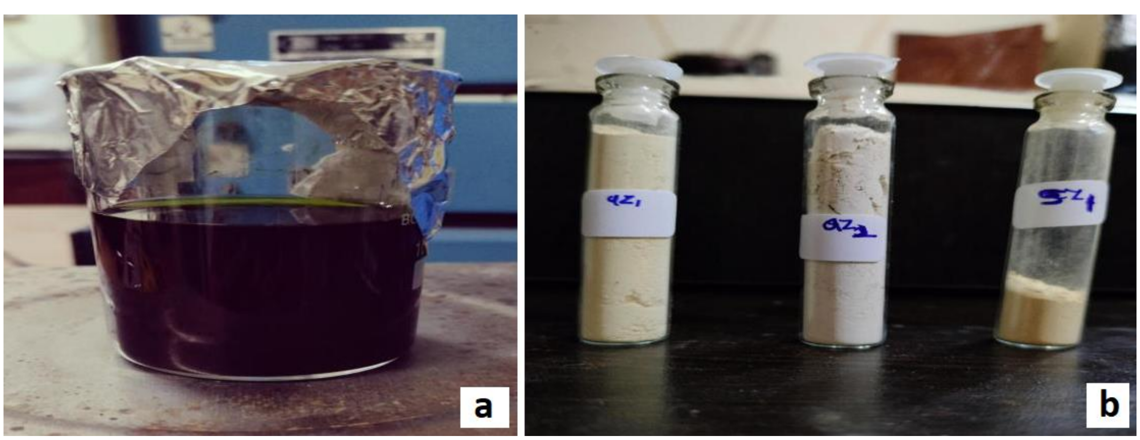

Fig.1.(a) *Aegle marmelos* leaves extract and **(b)** Zinc Oxide nanoparticles powder for three different ratios

3. Result and Discussion

Ultraviolet-Visible Spectral Analysis

The zinc oxide nanoparticles were characterized for their maximum absorbance using UV-Visible spectrophotometry. The optical property of zinc oxide nanoparticles was analyzed by Ultraviolet and Visible absorption spectroscopy in the range of 200-800 nm fig .2. shows the UV-Vis absorption spectrum of zinc oxide nanoparticles. Strong absorption bands of the biosynthesized samples were observed from UV-Vis spectra in the range of 324-358 nm which corresponds to the characteristic band of ZnO nanoparticles [21]. Absence of any other absorbance peak in the spectra confirms that the synthesized products are pure ZnO nanoparticles. The band gap energy was calculated using equation $Eg = 1240/\lambda eV$ and found to be 3.46, 3.60, and 3.82 eV for ZnO nanoparticles synthesized from 9:1,3:2and1:1 ratios respectively which is comparable to the previously reported values of energy band gap for ZnO nanoparticles [22,23]. The variation in Eg for the different ratios could be due to variation in the average crystal size of the nanoparticles.

Fourier Transform Infrared Analysis

The spectral properties of zinc oxide nanoparticles were observed by Fourier transform infrared spectroscopy analysis using the dried powder of the synthesized zinc oxide nanoparticles by FTIR spectrometer. FTIR spectrum of ZnO nanoparticles is shown in fig.3. The peak at 3445.08cm^{-1}, 3587.69cm^{-1}, and 3341.68cm^{-1} is due to C=O stretching and O-H stretching organic compound. The peak located at 1125.98cm^{-1}, 1114.05cm^{-1} and 1075.47cm^{-1}is due to the C-O stretching vibration, and 856.38cm^{-1},897.13 cm^{-1} and963.72cm^{-1}is due to N-H bending and C-H bending and 606.77cm^{-1}, 632.62cm^{-1}, and 675.46cm^{-1} are due to C-H bending respectively. It can be easily concluded that these phytochemicals are involved in stabilization and reduction of the zinc oxide nanoparticles. The peaks other than the phytochemicals peak occur at 575.08cm^{-1}, 562.46cm^{-1}, and 486.06cm^{-1} in the FTIR spectrum of the ZnO nanoparticles are the characteristic peaks of ZnO molecules.

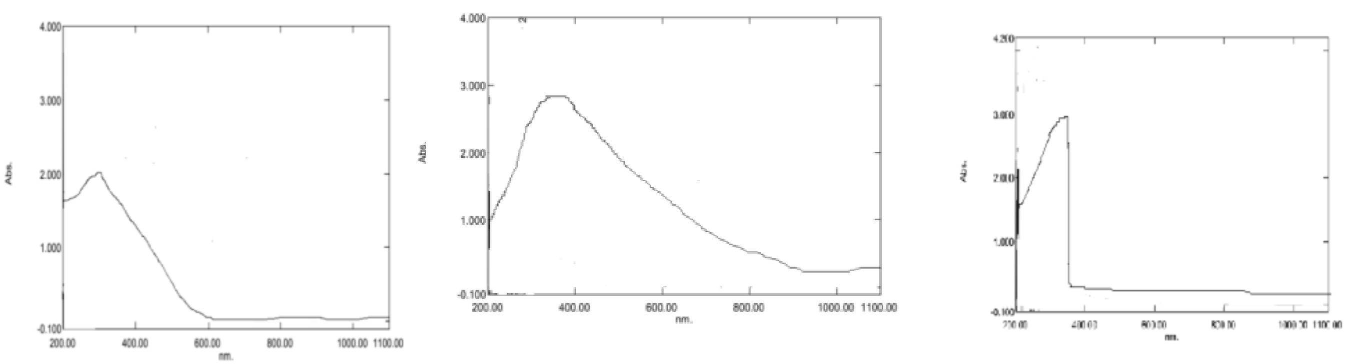

Fig.2 : UV-Visible absorption spectra of green synthesized ZnO NPs (a)1:1 ZnO, (b)3:2 ZnO, (c)9:1 ZnO NPs.

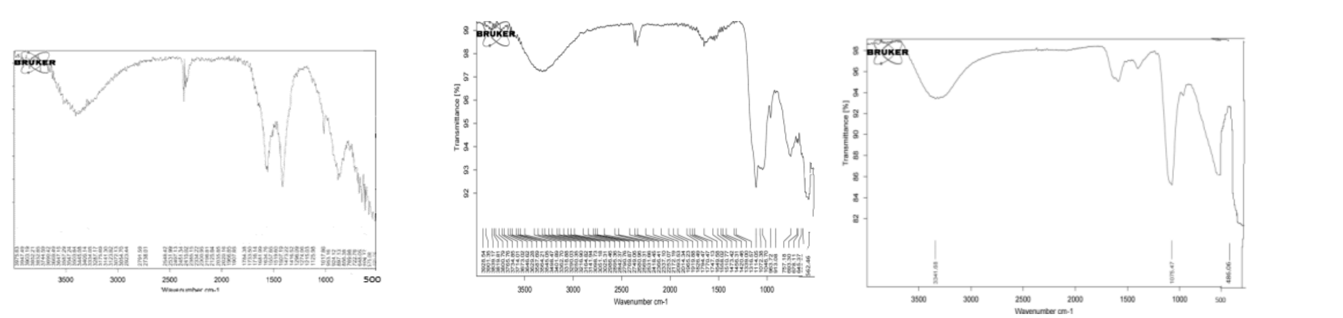

Fig.3. FTIR spectrum of ZnO NPs (a)1:1 ZnO, (b)3:2 ZnO, (c)9:1 ZnO NPs.

X-Ray Diffraction Analysis

Fig.4. shows the XRD pattern of zinc oxide nanoparticles synthesized using zinc acetate dehydrate and *Aegle marmelos* leaf extract using three different ratios by volume. The formation of biosynthesized ZnO nanoparticles was also confirmed by X-ray diffraction peaks that appeared at a 2θ value of 31.70^{0},34.38^{0},36.17^{0}, 32.62^{0}, 34.47^{0}, 35.77^{0}, 28.56^{0}, 32.95^{0},58.72^{0}. characteristic peaks for pure ZnO were observed in the XRD patterns confirming the formation of ZnO nanoparticles synthesized by using *Aegle marmelos* leaf extract and zinc acetate. The average crystal size of the biosynthesized zinc oxide nanoparticles was determined from the three most intense peaks using Debye Scherrer's equation. The result shows that the average crystal size of the biosynthesized ZnO nanoparticles decreased when the ratio of the plant extract decreased from 9:1 (51.32 nm) to 3:2 (21.03nm) and 1:1 (9.91nm) ratio by volume. This is decrease in crystal size due to use of greater amount of the plant extract during the synthesis process, there by resulting in effective capping, stabilization of the synthesized nanoparticles and hindered aggregation.

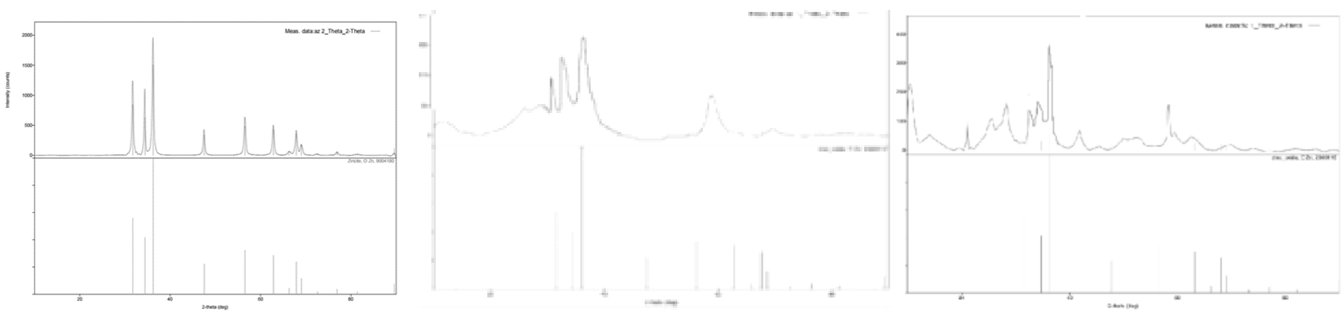

Fig.4.XRD pattern of ZnO NPs (a)1:1 ZnO, (b)3:2 ZnO, (c)9:1 ZnO NPs.

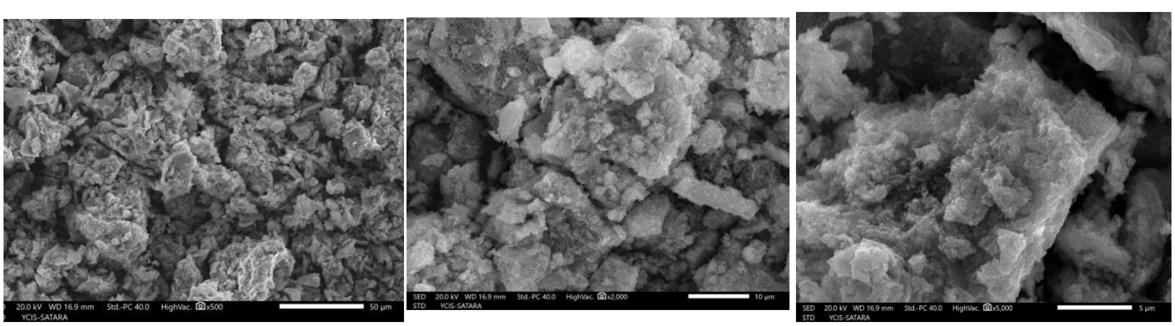

Fig.5.SEM images of (a)1:1 ZnO, (b)3:2 ZnO, (c)9:1 ZnO NPs.

Fig.6. Antibacterial activity against gram positive S.aureus bacteria for ZnO nanoparticles.

Scanning Electron Microscopy Analysis

The structural morphology of zinc oxide nanoparticles was examined and measured by scanning electron microscopy the SEM image is shown for prepared ZnO nanoparticles with *Aegle marmelos* leaves extract. According to the results, zinc oxide nanoparticles had a spherical morphology and the result are presented in Fig.4. and the particle size is estimated to be in the range of 40-60 nm.

Antibacterial Activity Analysis

The antibacterial activity of biosynthesized ZnO nanoparticles was investigated against selected pathogens such as Staphylococcus Aureus. The biosynthesized zinc oxide nanoparticles using *Aegle marmelos* leaf extract exhibited strong antibacterial activity against gram-positive S.aureus bacteria strains. the zone inhibition was examined 10 MM, 9MMand 8MM for 1:1,3:2 and 9:1 ratios respectively.

Conclusion

In this study, zinc oxide particles were successfully synthesized from the leaf extract of *Aegle marmelos* for the first time through a simple, cost-effective, eco-friendly, and green approach This showed that *Aegle marmelos* could be potentially used as an effective reducing and capping agent for biological synthesis of zinc oxide nanoparticles. The biosynthesized zinc oxide nanoparticles were characterized using XRD, SEM, FTIR, and UV-Vis. The crystallinity of the biosynthesized zinc oxide nanoparticles was proved from XRD analysis, XRD analysis showed that the average crystals sizes of zinc oxide nanoparticles synthesized from 1:1,3:2 and 9:1 ratio by volume were found to be 51.32nm, 21.05nm, 9.91nm. SEM analysis showed that the morphology of the biosynthesized ZnO was predominantly spherical. The optical band gap energies were determined from UV-Vis using the equation and found to be 3.46, 3.60, and 3.82 for ZnO nanoparticles synthesized from 1:1, 3:2, and 9:1 ratios by volume respectively. Further the biosynthesized ZnO nanoparticles using *Aegle marmelos* leaf extract have proved themselves to be an effective antibacterial agent against gram-positive S.aureus bacteria suggesting strong and promising action of green synthesized ZnO nanoparticles against the biological system.

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Conflicts of interest: The author stated that no conflicts of interest.

References

1. Bhardwaj A., Sharma G., Gupta S., Nanotechnology Application and Synthesis of Graphene as Nanomaterial for Nanoelectronics. In Nanomaterials and Environmental Biotechnology Bhushan I., Singh V., Tripathi D., Springer Switzerland,2020;pp251-269.
2. Prasanna VL., Vijayaraghavan R. Insight into the mechanism of antibacterial activity of ZnO surface defects mediated reactive oxygen species even in the dark *Langmuir.,* 2015; 31;9155-9162.
3. Zhong L, Liu H, Samal M, et al synthesis of ZnO nanoparticles decorated spindle-shaped graphene oxide for application in synergistic antibacterial activity. *J Photochem Photobial B-Biol.*, 2018;183;293-301.
4. Fujihar S. Naito H. Kimura T. visible photoluminescence of ZnO nanoparticles dispersed in highly transparent MgF2 thin films via sol-gel prosses. Thin solid films 2001; 289; 227-232.
5. Mochinaga R, Yamasaki T, Arakawa T, The gas sensing of SmCoOx/MOx having a heterojunction, *Sence actuator B Chem.*, 1998;52;96-99.
6. Siyanbola To, Sasidar K, Anjaniyulu B, et al antimicrobial and anticorrosive poly siloxane modified ZnO hybrid coatings from Thevetia Peruvian seed oil. *J Mater sci*. 2013; 48;8215-8227.
7. Kumar S., Alhavat W,. Kumar R., et al graphene carbon nanotubes zinc oxide and gold as an elite nanomaterial for fabrication of biosensor for healthcare. *Bioscience Bioelectron*, 2015; 70;498-503.
8. Raghupati KR., Koodali RT., Manna AC., size-dependent bacterial growth inhibition and mechanism of antibacterial activity of zinc oxide nanoparticles *Langmuir.* 2011;27;4020-4028.
9. Rosi NL, Merkin CA. Nanostructure in biodignostic. *Chem. Rev.*, 2005;105;1547-1562.

10. Buazar F.,Baghalani-Nejazed ,M.H.; Badri M.,Kashisaz M.,Nasab A.,Khalidi Nasab ,A;Kroushawi,F.Fcile one pot Photosynthesis of magnetic nanoparticles using potato extract and their catalytic activity. *Starch stark* 2016; 68: 796-804.

11. Shobha K., Surendranath K., Meena V., Jawala, T K Swetha N Latha K.S. emerging trend in nanobiotechnology. *Biotechnol.MolBiol* 2010;4;1-12.\

12. Xie J., Lee. J. Y., Wang D.I., Ting Y.P., Silver nanoplate from biological to biomematic synthesis ACS nano 2007;1;429-439.

13. Iravani S., Green synthesis of metal nanoparticles using plants.Green chem. 2011,13,2638-2650.

14. Agrwal H., Nakara A.; Shanmugam, V.K. Anti-inflammatory mechanism of various metal and metal oxide nanoparticles synthesized using plant extract A. review. *Biomed*. 2019,109,2561-2572

15. Shaikh F.,Panhwar QK. Balouch A., Ali S Panhwar W.A., Shaikh F., Synthesis of zinc oxide nanoparticles and their functionalization with chrysin.Exploration of its application, *Int J.Environ.Anal.Chem.*2020.1-10.

16. Selim Y.A., Azb. M.A., Ragab I., Abd EI., Azim,MH. Green synthesis of Zinc Oxide nanoparticles using aqueous extract of Deverro Tortuosa and their cytotoxic activities *Sci. Rep.2020*.10, 1-9.

17. Ramesh P. Rajendran A., Meenakshisundaram M., Green Synthesis of zinc oxide nanoparticles using Flower extract *Cassia Auriculata.J. nanosci.nanotechnology* 2014,2, 41-45

18. Sastri M.A. Ahamad.,M. Islam Khan R. Kumar Biosynthesis of metal nanoparticles using fungi and actinomycete, *Curr sci., 20*03.162-170.

19. Rao M.D., P. Gautam Synthesis and characterization of ZnO nanoflower using clamadomonas reinharditii; Agreen approach, environ prog sustain energy2016.1-7.

20. Sharmila D.R. and R. Gayathri, Green synthesis of zinc oxide nanoparticles by using Hibiscus Rosa since *International journal of current engineering and technology,* 2014.1137.

21. Salauddin A.A., W.F. Kamary, E.M. Ebrahim, et al, synthesis and characterization of ZnO nanoparticles via precipitation method effect of annealing temp on particle size *journal of nanoscience and nanotechnology*, 2015.82-218.

22. Tan S.T., B.J. Chen, X.W.Sun, X.H. Zhang Blue shift of optical band gap in ZnO thin film grown by metal-organic deposition J Appl Phys.2005.98.

23. Debanath M.K., S. Karmakar, the study of blue shift of optical band gap in zinc oxide nanoparticles prepared by low-temperature wet chemical method mater Lett. 2013.116-119.