Journal of Pharmaceutical Research International

33(61B): 354-362, 2021; Article no.JPRI.82741
ISSN: 2456-9119
(Past name: British Journal of Pharmaceutical Research, Past ISSN: 2231-2919, NLM ID: 101631759)

Biogenesis of Zirconium Oxide Nanoparticles by *Momordica charantia* (Bitter Gourd) Leaf Extract: Characterization and their Antimicrobial Activities

P. Subramanian [a≡] and S. Alwin David [b≡*]

[a] Department of Educational Planning and Administration, Tamil Nadu Teachers Education University, Chennai – 97, India.
[b] PG and Research Department of Chemistry, V. O. Chidambaram College, Tuticorin - 628 008, Affiliated to Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli - 627 012, Tamilnadu, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author SAD designed the study, performed the synthesis, characterization, and applications, and wrote the first draught of the manuscript. Author PS managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JPRI/2021/v33i61B35608

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/82741

Original Research Article

Received 22 October 2021
Accepted 27 December 2021
Published 28 December 2021

ABSTRACT

Aims: To determine the antimicrobial activity of zirconium oxide nanoparticles (ZrO_2 NPs) synthesized by *Justicia Adhatoda* leaf extract.
Study Design: Synthesis, characterization and antibacterial activity determination of ZrO_2 NPs.
Place and Duration of Study: PG and Research Department of Chemistry, V.O.Chidambaram College, Tuticorin, Tamilnadu, India, between April 2020 and April 2021.
Methodology: *Justicia adhatoda* leaf extract was used to synthesize ZrO_2 NPs. UV-Visible spectroscopy was used to characterize ZrO_2 NPs. Using Fourier transform infrared spectroscopy, the function of biomolecules in plant extract in the synthesis of ZrO_2 NPs was identified. XRD was used to determine the particle size of nanparticles. ZrO_2 NPs were evaluated for antimicrobial activity.
Results: The synthesis of ZrO_2 NPs was clearly visible in an absorbance band at 321 nm in the UV–visible spectrum. The absorption peak of ZrO_2 NPs in the FTIR was 880 cm^{-1}, confirming the

[≡]Assistant Professor;
**Corresponding author: E-mail: alwindavid1986@gmail.com;*

Zr–O vibrational mode in ZrO_2 NPs. As evidenced by XRD measurements, the average crystallite size of ZrO_2 NPs was found to be 40 nm. The biosynthesized ZrO_2 NPs were found to have potent antibacterial action against *Escherichia coli* bacteria and *Staphylococcus aureus* bacteria.
Conclusion: ZrO_2 NPs mediated by *Justicia adhatoda* leaf extract have demonstrated substantial antibacterial activity

Keywords: Green synthesis; zirconium oxide nanoparticles; Justicia adhatoda; antibacterial activity.

1. INTRODUCTION

Metal oxides have been analysed by intensive investigators due to their low cost, variable oxidation states, excellent physical and chemical properties, and several industrial applications [1,2]. Zirconium oxide (ZrO_2), often known as zirconia, is a versatile material that has been employed in a wide range of applications, including structural reinforcement, antibacterial agents, adsorption, and photodegradation [3,4].

The well-known procedures for the synthesis of nanoparticles necessitate the use of expensive, caustic, hazardous, and combustible chemicals, which are frequently hazardous to the environment and human health. As a result, the development of a green approach for nanoparticle synthesis has recently received a lot of interest. Green synthesis generates nanoparticles that are free of pollution, low cost, biocompatible, and non-toxic, in addition to being environmentally benign as compared to other physiochemical processes.

Plant extracts, bacteria, yeast, fungi, actinomycetes, lichen, or algae have been proposed as green alternatives to physiochemical methods for metal oxide nanoparticle synthesis. Plant extract-based nanoparticle synthesis is less expensive than microbial-based synthesis, which is more expensive due to the high cost of microbe cultivation. Plant extract-mediated nanoparticle synthesis is thought to be more efficient than microbial-mediated nanoparticle synthesis because plant extracts include a variety of bioactive compounds that can be used as reducing and stabilising agents. Thousands of plant extracts have been discovered to have the ability to reduce metal salts to metal oxides.Plant extracts like *Ficus benghalensis, Alium cepa, Eucalyptus globules, Lagerstroemia speciosa, Acalypha indica, Acalypha indica, Euclea racemosa* have been used for the synthesis of ZrO_2 nanoparticles [5-8]

Momordica charantia is a subtropical and tropical vine that is widely cultivated for its edible fruit throughout Asia, Africa, South America, and the Caribbean. Bitter gourd, bitter melon, kerela, and balsam pear are all frequent names for this exceedingly bitter fruit plant. It has antidiabetic, antibacterial, antileukemic, anticancerous, antiprotozoal, antitumorous, anti-obesity, antiparasitic, antifungal, anti-ulcer, immune stimulant, hypoglycemia, and antiviral properties and can be used as medicine [9].

Momordica charantia has been used for diabetes, psoriasis, leukaemia, high cholesterol, tumour aetiology, cancer, viral infections, and bacterial infections in African and Asian herbal medicine systems. Triterpenes, proteins, momordicin, charantin, steroids, alkaloids, ascorbic acid, gallic acid, ferulic acid, tannic acid, catechin, caffeic acid, and other phenolic compounds have been found in *Momordica charantia*, which are responsible for the therapeutic effects [10,11].

From a comprehensive literature survey, it is noted that this is the first report on ZrO_2 nanoparticle synthesis using the leaf extract of *Momordica charantia.*

2. MATERIALS AND METHODS

2.1 Chemicals Used

Zirconyl chloride ($ZrOCl_2$) used for the synthesis of ZrO_2 NPs was purchased from Sigma Aldrich. Healthy and fresh leaves of *Momordica charantia* were collected from the Thoothukudi, Tamilnadu, India.

2.2 Preparation of *Momordica charantia* Leaf Extract

Fresh *Momordica charantia* leaves weighing around 10g were properly cleansed with running tap water and then distilled water to remove dust particles. In a round-bottom flask with a condenser, finely crushed *Momordica charantia* leaves were heated in 100 mL of distilled water for 1 hour at 100°C. The leaf extract was filtered using the Whatman No. 41 filter paper that was used in the ZrO_2 NP synthesis.

Zirconyl chloride ($ZrOCl_2$)

***Momordica charantia* leaves**

Fig. 1. Chemicals used

2.3 Biosynthesis of ZrO_2 NPs

For the synthesis of ZrO_2 NPs, zirconyl chloride ($ZrOCl_2$) and *Momordica charantia* leaf extract were utilised as the precursor salt and reducing agent, respectively, for the synthesis of ZrO_2 NPs.

In a round-bottom flask with a condenser, 25 mL of *Momordica charantia* leaf extract was added to 75 mL of 0.5 M Zirconyl chloride solution and 25 mL of 0.1 M NaOH. This combination was heated for 2 hours at 100°C. The synthesized ZrO_2 NPs were then filtered and dried overnight in an oven at 60°C.

2.4 Characterization of ZrO_2 NPs

The UV-Visible spectra of the ZrO_2 NPs and *Momordica charantia* leaf extract were recorded on JASCO UV-Visible spectrometer. FTIR measurements were performed on a Thermo Scientific Nicolet iS5 instrument in the diffuse reflectance mode at a resolution of 4 cm^{-1} in KBr pellets. The average particle size of ZrO_2 NPs was determined by using XPERT-PRO X-ray diffractometer operating at a voltage of 40 kV and a current of 30 mA with Cu Kα radiation.

2.5 Antibacterial Activity

The following approach was used to test ZrO_2 NPs biosynthesized from *Momordica charantia* leaf extract for antibacterial activity against *Escherichia coli* and *Staphylococcus aureus.* Muller-Hinton agar medium was prepared and autoclaved for 15 minutes at 121°C. In the inoculation chamber, the agar medium was transferred to petri plates under aseptic conditions and allowed it to solidify. The test sample-loaded filter paper discs were placed on top of the bacterial liquid culture that has been swabbed uniformly across the agar surface. As a control, ampicillin-loaded discs were used. It was incubated for 24 hours at 37°C. Measurement of the inhibitory zone was taken.

3. RESULTS AND DISCUSSION

Characterizations and applications of ZrO_2 NPs were done by various techniques. The results obtained are discussed in detail as follows:

3.1 UV-Visible Spectroscopic Analysis

The optical characteristics of metal oxide nanoparticles can be determined using UV-Visible spectroscopy, which is one of the most potent techniques for characterization of metal oxide nanoparticles.

Two absorption bands at 270 nm and 315 nm observed from *Momordica charantia* leaf extract are attributable to UV absorption of polyphenols, as illustrated in Fig. 2. It demonstrates the presence of polyphenols in *Momordica charantia* leaf extract, which may be responsible for the green production of ZrO_2 NPs as a reducing agent.

The UV-visible spectrum of green synthesised ZrO_2 NPs is shown in Fig. 3. The spectrum displays one absorption peak at around 321 nm, which corresponds to the zirconium oxide nanoparticle absorption maxima. The valence-to-conduction band transition of ZrO_2 NPs causes the absorption peak at 321 nm [8].

3.2 FTIR Analysis

To identify the probable biomolecules responsible for the synthesis of ZrO_2 NPs, FTIR measurements of *Momordica charantia* leaf extract and ZrO_2 NPs were taken.

The results of FTIR of *Momordica charantia* leaf extract (Fig. 4) show a number of absorption bands at 619, 1108, 1409, 1572, 2929 and 3409cm^{-1}. In which, the band at 619cm^{-1} corresponds to mono substituted aromatic stretching. The band at 1108cm^{-1} is characteristic of C-C stretching vibrations of aromatic amines. The band at 1409 cm^{-1} could be due to the C-H stretching vibration. The band at 1572 cm^{-1} region is characteristic of C-O asymmetric stretching vibration. The band observed at 2929 cm^{-1} may be due to the C-H stretching vibration. The broad band at 3409cm^{-1} is due to the stretching vibration of hydroxyl group. The majority of the FTIR bands are characteristic of alkaloids, flavonoids, terpenoids, steroids, proteins, carbohydrates and other phenolic compounds present in the *Momordica charantia* leaf extract [9].

The FTIR spectrum of ZrO_2 NPs (Fig. 5) shows major peaks at 880, 1456, 1636, 2924 and 3434cm^{-1}. The spectrum clearly shows bands for C-O asymmetric stretching vibration and hydroxyl group stretching vibration at around 1636 and 3434 cm^{-1} respectively. The band at 1456 cm^{-1} could be due to the C-H stretching vibration. The band observed at 2924 cm^{-1} may be due to the C-H stretching vibration. The lower absorption bands at about 880 cm^{-1} is attributed to the Zr–O vibrational mode as reported for many ZrO_2 NPs [8,9].

3.3 X-ray Diffraction Analysis

The crystallite size can be evaluated using Debye-Scherer equation:

$$D = \frac{k \times \lambda}{\beta \cos\theta}$$

where D is the thickness (diameter) of the particle, λ is the wavelength of the X-ray beam, β is the full width at half maximum (FWHM) of the peak position in radians, k is the shape factor (0.9) and θ is the Bragg diffraction angle at peak position [8,9].

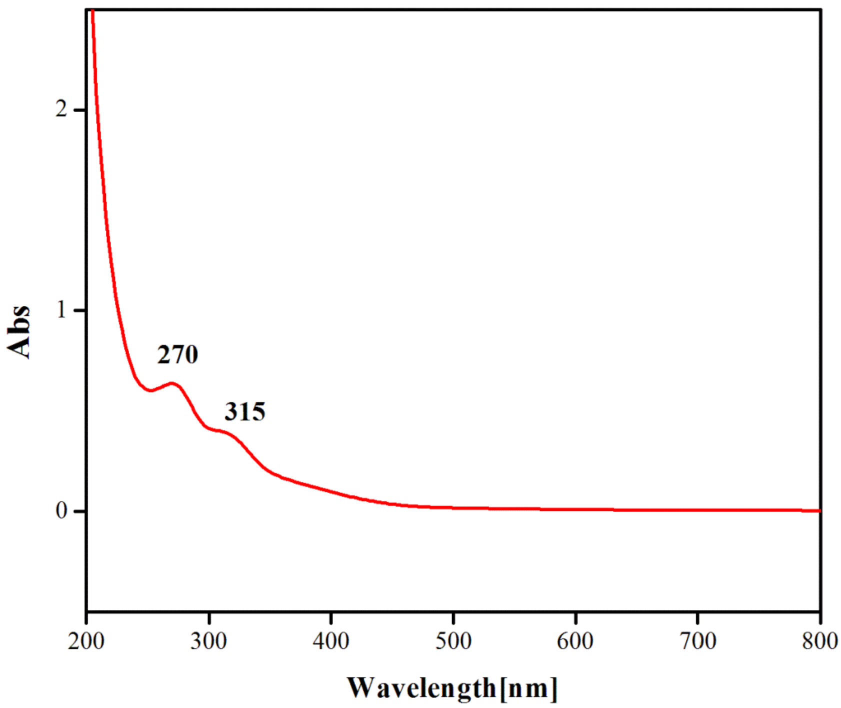

Fig. 2. UV-Visible spectrum of *Momordica charantia* leaf extract

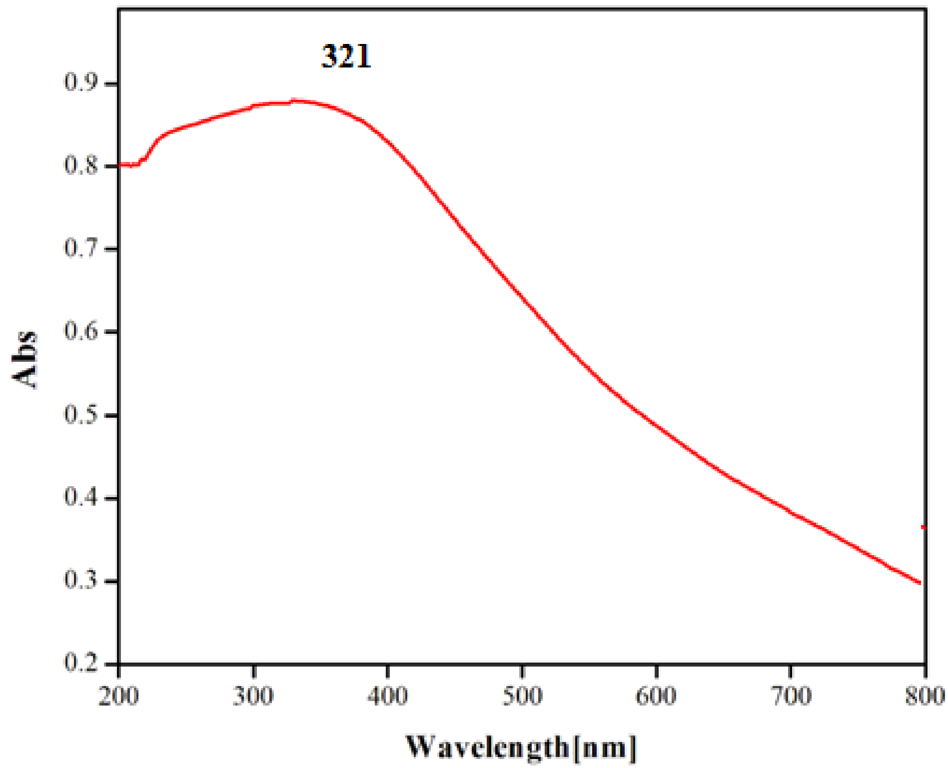

Fig. 3. UV-Visible spectrum of ZrO_2 NPs

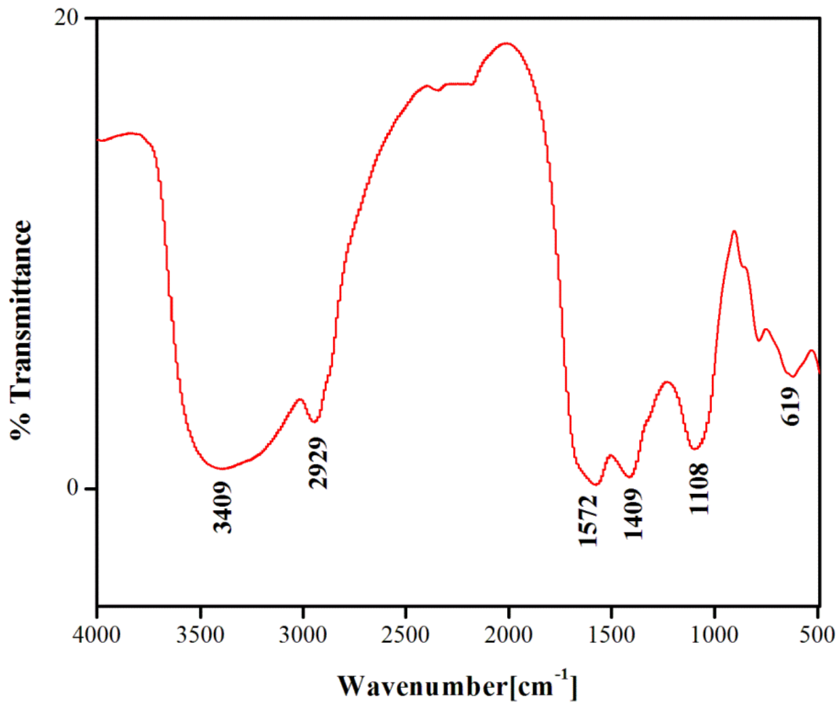

Fig. 4. FTIR spectrum of *Momordica charantia* leaf extract

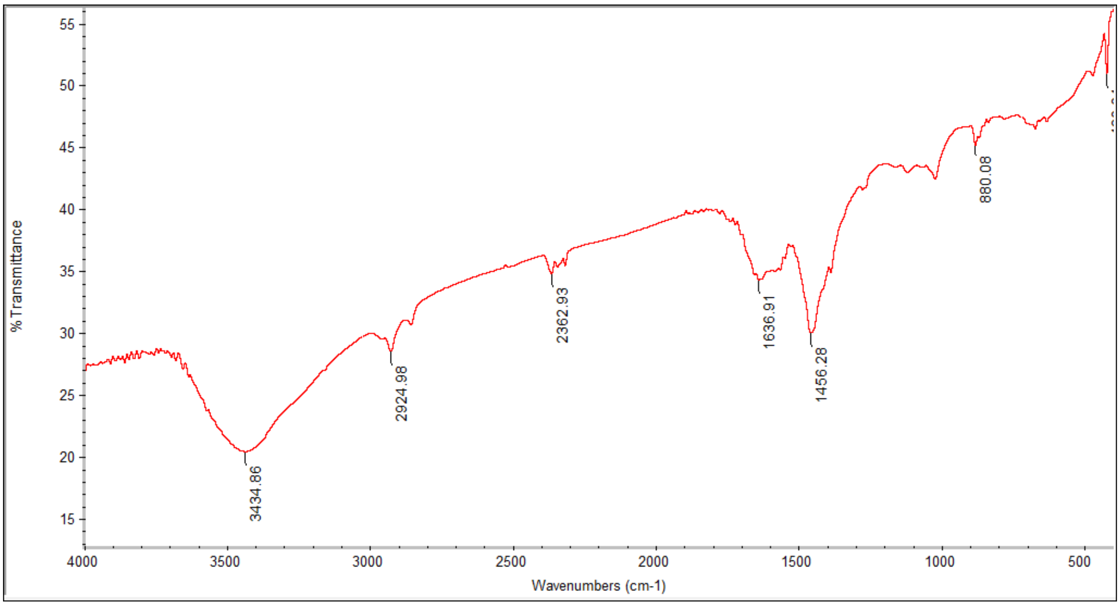

Fig. 5. FTIR spectrum of ZrO_2 NPs

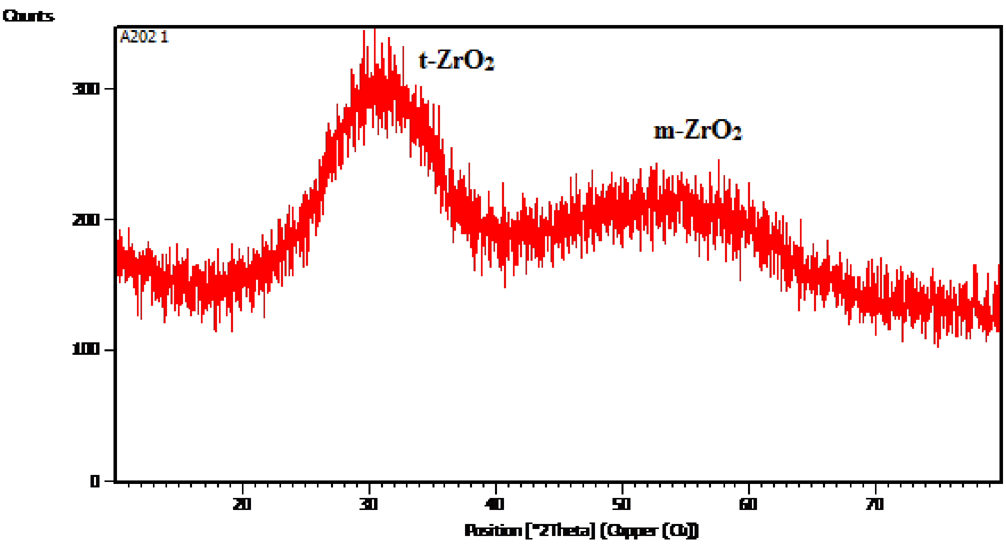

Fig. 6. XRD pattern of ZrO_2 NPs

From XRD data, the average crystallite size of the ZrO_2 NPs as estimated using the Scherrer formula is 40nm. Fig. 6 show the XRD pattern of the synthesized ZrO_2 nano particles. There is a broad peak corresponding to 100% reflection of t-ZrO_2 besides there is a narrow peaks corresponding to m-ZrO_2 were also identified. The formation of t-ZrO_2 as the main phase of zirconium nano particles could be related to the presence of sodium hydroxide in the generation stage [12].

3.4 Antimicrobial Activity

Fig. 7 illustrates the antibacterial activity of biosynthesized ZrO_2 NPs against *Escherichia coli* and *Staphylococcus aureus*. Bio-generated ZrO_2 NPs have antibacterial efficacy against *Escherichia coli* (zone of inhibition of 11 mm) and *Staphylococcus aureus* (zone of inhibition of 10 mm).

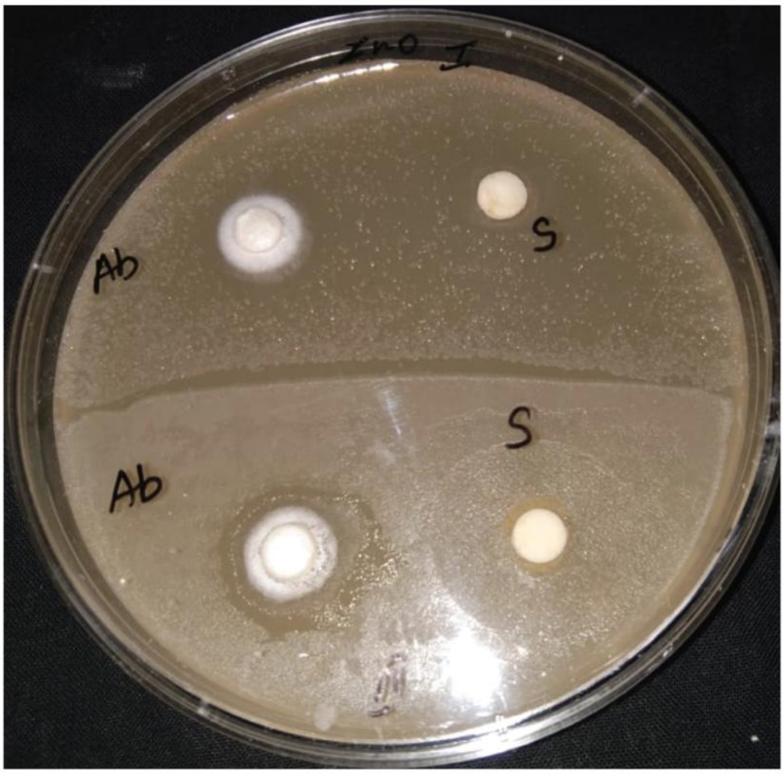

Fig. 7. Antibacterial activity of ZrO_2 NPs against (I) *Escherichia coli and* (II) *Staphylococcus aureus*

Table 1. Antibacterial activity data of ZrO_2 NPs

Bacteria	**Inhibition zone in mm Concentration 1mg/ml Ab→Ampicillin**	**S → ZrO_2 NPs**
 ***Escherichia coli***	14	11
 ***Staphylococcus aureus***	19	10

4. CONCLUSION

The biosynthesis of ZrO_2 NPs using *Momordica charantia* leaf extract is demonstrated, with phenolic chemicals perhaps acting as a reducing agent. UV-Visible spectra with absorption bands centred around 321nm confirm the production of ZrO_2 NPs. The presence of a Zn–O bond is confirmed by bands in the FT-IR spectrum at 880 cm^{-1}. According to the XRD pattern, ZrO_2 NPs have an average particle size of 40 nm. The antimicrobial activity of ZrO_2 NPs against *Escherichia coli* and *Bacillus cereus* is substantial.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

ACKNOWLEDGEMENTS

The authors are grateful to the Department of Science and Technology (FAST TRACK) New Delhi for UV –Visible spectroscopic analysis and FTIR spectroscopic analysis at V.O. Chidambaram College.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Alwin David S, Subramanian P. Antibacterial Activity of CuO nanoparticles synthesized by *Justicia adhatoda* leaf extract. Journal of Pharmaceutical Research International. 2021;33(56B):160-170.
2. Alwin David S, Veeraputhiran V, Vedhi C. Biosynthesis of cobalt oxide nanoparticles - A review. Journal of Nanoscience and Technology. 2019;5(3):734-737.
3. Alwin David S, Vedhi C. Synthesis and Characterization of Co_3O_4 - CuO - ZrO_2 Ternary Nanoparticles. International Journal of Chem Tech Research. 2017;10:905–912.
4. Uddin I, Ahmad A. Bioinspired eco-friendly synthesis of ZrO_2 nanoparticles. Journal of Materials. 2016;7(9):3068-3075.
5. Jalill RDA, Jawad MMHM, Abd AN. Plants extracts as green synthesis of zirconium oxide nanoparticles. J. Genet. Environ. Res. Conserv. 2017;5(1):6-23.
6. Shanthi S, Tharani SSN. Green synthesis of zirconium dioxide (ZrO_2) nano particles using Acalypha indica leaf extract. International Journal of Engineering and Applied Sciences. 2016,3(4):1.
7. Sathishkumar M, Sneha K, Yun YS. Green fabrication of zirconia nano-chains using novel Curcuma longa tuber extract. Materials Letters. 2013;98:242-245.
8. Shinde HM, Bhosale TT, Gavade NL. S. B, Babar RJ, Kamble BS, Shirke KM, Garadkar. Biosynthesis of ZrO_2 nanoparticles from *Ficus benghalensis* leaf extract for photocatalytic activity. J Mater Sci: Mater Electron. 2018;29:14055–14064.
9. Alwin David S, Ponvel KM, Fathima MA, Anita S, Ashli J, Athilakshmi A. Biosynthesis of silver nanoparticles by Momordica charantia leaf extract: Characterization and their antimicrobial activities. Journal of Natural Product and Plant Resources. 2014;4(6): 1-8.
10. Saeed MK, Shahzadi I, Ahmad I, Ahmad R, Shahzad K, Ashraf M. Nutritional analysis and antioxidant activity of bitter gourd (*Momordica Charantia*) from Pakistan. Pharmacologyonline. 2010;1: 252-260.
11. Budrat P, Shotipruk A. Extraction of phenolic compounds from fruits of bitter melon (*Momordica charantia*) with subcritical water extraction and antioxidant activities of these extracts. Chiang Mai J Sci. 2008;35(1):123-130.

12. Chikere CO, Faisal NH, Kong-Thoo-Lin P, Fernandez C. Interaction between amorphous zirconia nanoparticles and graphite: electrochemical applications for gallic acid sensing using carbon paste electrodes in wine. Nanomaterials. 2020; 10(3):537.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/82741