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Prosopis Juliflora Leaf Extract Mediated Synthesis Of Doped Tin Oxide Nanoparticles And Evaluation Of Antimicrobial Activity

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ABSTRACT

Nanomaterials are used in a wide range of industries, including storing energy, water treatment, nanomedicine, fuel cells, sensing, catalysis, optoelectronics, and tunable resonant devices. Varieties of metals used for the preparation of nanoparticles. SnO_2 is a prominent n-type wide-bandgap semiconductor, and due to the variety of controllable physicochemical features of SnO_2-based nanostructures, they are emerging as one of the most significant classes. Therefore, the development of a more efficient nanomaterial with enhanced antimicrobial activity of great significance. The objective of this study was to synthesize 2% F doped Tin dioxide (SnO_2) (FTO) nanoparticles using *Prosopis Juliflora* leaf extract and determine its antimicrobial activity against selected microbial strains. The characterization of synthesized nanoparticles were investigated by scanning electron microscopy, transmission electron microscopy, UV–Vis–IR spectroscopy. The grain sizes in the range of 16-26 nm were obtained. The antimicrobial activities of F- doped SnO_2 nanoparticles were studied against bacteria (*Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis*) and fungi (*Aspergillus flavus* and *Aspergillus niger*) using the standard disc diffusion method. The antimicrobial activity was increased directly proportional to dose-dependent manner. Experimental results demonstrated that 2% F doped Tin dioxide (SnO_2) nanoparticles (F- doped SnO_2) exhibited the good antimicrobial effects were observed.

Keywords: Nanoparticles, Characterization, *Prosopis Juliflora* leaf, F- doped SnO_2, Antimicrobial activity.

INTRODUCTION

Nanotechnology is the study of nanoparticles, the size of its atomic and molecular aggregates is less than 100nm. Nanotechnology is one of the emerging fields because of its uses in various sectors of medicine, technology and in the field of research including electronics, optics, biomedical and material sciences. Nanoparticles are reduced to nano-scale size to influence their mechanical, chemical, structural, electrical, morphological, and optical properties (Rasmussen et al., 2010). Nanoparticles have larger structure with respect to their counterparts due to its small size. And this allows the possible applications of NPs in various biological fields such as biosensors, nanomedicine, and bio-nanotechnology (Ashe, 2011). Thus, nano-materials play an important role in the basic and practical sciences as well as in bio-nanotechnology (Zhang *et al.* 2012). SnO_2 is a prominent n-type wide-bandgap semiconductor, and due to the variety of controllable physicochemical features of SnO_2-based nanostructures, they are emerging as one of the most significant classes. Many studies have recently reported the synthesis of SnO_2-based nanocomposite materials, which can significantly improve performance (Gebreslassie and Gebretnsae, 2021). Elemental doping is one of the most

essential techniques for material modification. It is well known that fluorine is considered to be a highly efficient and inexpensive dopant in the field of materials. Fluorine is one of the most reactive elements with the highest electronegativity. F-doped ZnO has been synthesized by various techniques (Jiale Huo *et al.*, 2023).

Bacterial and fungal infections are a major cause of chronic infections and mortality. Antibiotics have been the preferred treatment method for bacterial infections because of their cost-effectiveness and powerful outcomes. Therefore, the development of more efficient material with enhanced antimicrobial activity is of great significance. Despite the great progress in antimicrobial development, many infectious diseases like intracellular infections are difficult to treat (Matthews et al., 2010). Major reasons of difficulty are transportation through cell membranes, low activity in the cells, antimicrobial toxicity to healthy tissues and acquired resistance of infectious microbes (Deotale et al., 2010) To address these issues, nanoscale materials have been emerged up as novel antimicrobial agents. Nanoparticles (NPs) are ideal forms of antimicrobial agents because these materials exhibit large surface to volume ratio and high reactivity in comparison to bulk form (Reddy et al., 2007). Many NPs have antimicrobial properties and used to control drug-resistant microbial populations. Various inorganic metal oxide NPs viz., ZnO, MnO, TiO_2 and SiO_2 exhibit considerable antimicrobial activities and used in therapeutics, diagnostics and nanomedicine-based antimicrobial agents (Mukherjee *et al.*, 2011; Sobha *et al.*, 2010). synthesize 2% F doped Tin dioxide (SnO_2) nanoparticles using *Prosopis Juliflora* leaf extract and determine its antimicrobial activity against selected microbial strains.

MATERIALS AND METHOD

Collection of plant materials

The leaves of *Prosopis Juliflora* were collected in January 2021 from Poondi, Thanjavur District, Tamil Nadu, India.

Preparation of aqueous extract of *Prosopis Juliflora* leaf

The collected leaves were washed with double distilled water to remove dust particles and then dried in the shade for two days for remove wet condition. 20 g of leaf sample was mixed 100ml of deionized water and the mixture was boiled for 30 min. after cooling the leaf extract was filtered with whatman no.1 filter paper. The filtrate was stored at 4 decree C for further uses.

Synthesis of F-doped SnO_2 nanoparticles using *Prosopis Juliflora* (PJ) leaf extract

For synthesis of F doped SnO_2 NPs, 0.1 M $SnCl_2 \bullet 2H_2O$ solution and Ammonium fluoride were used as dopant precursors F (2%) was prepared with 80 mL water. Then 20 mL *Prosopis juliflora* leaf extract was added and 0.1 M NaOH solution added maintain pH level 6-7 to solution and kept under continuous stirring at 80°C for 2 h. The F-SnO_2 PJ NPs were then collected with annealing the sample in a furnace at 350 deg C for 3 h. F-SnO_2 nanoparticles collected and involved character study and application. Preparation F-SnO_2 nanoparticles by co-precipitate method.

Characterization of nanoparticles

UV and FTIR Spectroscopic analysis

The nanoparticles were examined under UV and visible spectrophotometer analysis. The nanoparticles were scanned within the wavelength starting from 200-1000 nm using Perkin Elmer photometer and also the characteristic peaks were identified. FTIR analysis was performed using Spectrophotometer system, which was used to detect the characteristic peaks in ranging from 400-4000 cm^{-1} and their functional groups. The peak values of the UV and FTIR were recorded. Each and every analysis was repeated twice for the spectrum confirmation

Scanning Electron microscopy (SEM)

The particle size and morphology of nanoparticles were analysed by ZEEISS-SEM machine. The dried form of silver nanoparticles were sonicated with distilled water, small droplet of silver nanoparticles were placed on glass slide and permitted to dry. The ZEEISS-SEM machine was worked at a vacuum of the order of 10-5 torr. The accelerating voltage is 20 kV. The particle size of nanoparticles can be analyzed by using image magnification software compatible with SEM.

Transmission Electron microscopy (TEM)

Transmission electron microscopy (TEM) technique was used to visualize the morphology of the nanoparticles. The make of the Transmission electron microscope (TEM; Philips model CM200) technique was to visualize the morphology of nanoparticles. The instrument was operated at an accelerating voltage of 200 kV with ultra-high-resolution of 0.2 nm and magnification of 2,000,000 X. TEM's grid size is 3 mm diameter which was prepared placinga 5µl of the nanoparticle solutions on carbon-coated copper grids and drying under mercury lamp and then analyzed

Determination of antimicrobial activity

The antimicrobial activity was performed by disc diffusion method followed by NCCLS (1993) and Awoyinka *et al.*, (2007). Antibiogram was done by disc diffusion method using test sample. Petri plates were prepared by pouring 30 ml of NA medium for bacteria. The test organism was inoculated on solidified agar plate with the help of micropipette and spread and allowed to dry for 10 mints. The surfaces of media were inoculated with bacteria from a broth culture. A sterile cotton swab is dipped into a standardized bacterial test suspension and used to evenly inoculate the entire surface of the Nutrient agar plate while PDA used for fungal study. Briefly, inoculums containing of bacteria (*Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis*) and fungi (*Aspergillus flavus* and *Aspergillus niger*) were spread on agar plates. Using sterile forceps, the sterile filter papers (6 mm diameter) containing different concentration of sample (50, 100, 150 and 200 µl), 30µl deionized water (control) and 30µl Standard (Bacteria: Chloramphenicol and Fungi : Clotrimazole) solution were laid down on the surface of inoculated agar plate. The plates were incubated at 37 °C for 24 h for the bacteria.

RESULTS AND DISCUSSION

UV–Vis spectroscopy is the most important technique and the simplest way to confirm the formation of nanoparticles. In the UV -Visible absorption spectrum of F-SnO_2 nanoparticle showed a clear absorption peak was observed at the wavelength 325 nm (Figure 1). Present study agreement with Lisnic *et al.* (2023) who reported that absorption peak was observed at the wavelength 350nm from Fluorine-Doped SnO_2 Thin films in solar cell applications.

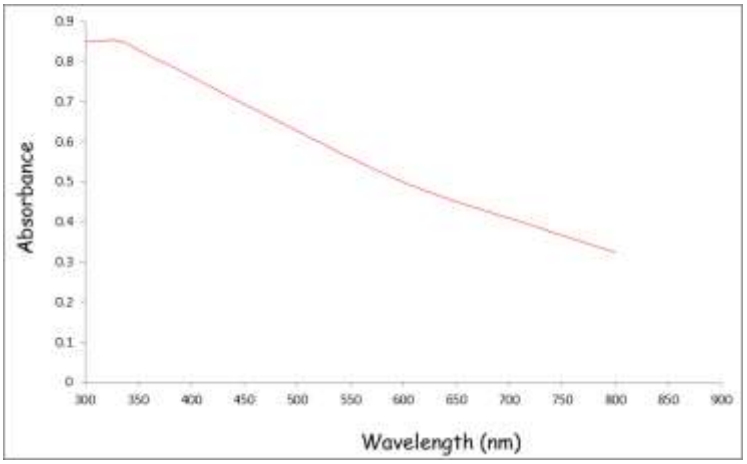

Figure 1: UV-Visible Spectroscopic analysis of 2% F-doped SnO_2 nanoparticles

FTIR Spectroscopic analysis

The FTIR spectra of F-doped SnO_2 films are illustrated in Figure 2. The spectrum is formed with several absorption peaks assigned to Vibrational modes of F-SnO_2 confirming its formation. The obtained spectra are comparable to the reported ones in the literature ((Kim and Riu, 2011; Kar and Kundoo, 2015). The spectrum shows several absorption peaks which confirm the formation of the material. Peaks (618 cm^{-1}, 876 cm^{-1}) between 500-1000 cm^{-1} assigned to Sn-O and Sn-O-Sn vibration (Van Tran *et al.*, 2010). Small peaks (618.31 cm^{-1}) between 600 - 1900 $cm^{-1}$are due to Sn-OH vibration. An additional peak located at 876 cm^{-1}, which becomes inconspicuous as fluorine concentration increases can be assigned to oxygen vacancies (V^{2+}) presence in the O-Sn-O group (Zhang et al., 2011). Broad peak (3428.00 cm^{-1}) 3000- 3500 cm^{-1} is due to O-H stretching vibration. Peak at 1161 cm^{-1} occurs due to Si-O vibration due to substrate. FTIR spectra were obtained to identify the possible biomolecules in the extract responsible for predicting their role in nanoparticle synthesis and the reduction of ions as well as the capping agents for the stability of biogenic nanoparticle solution.

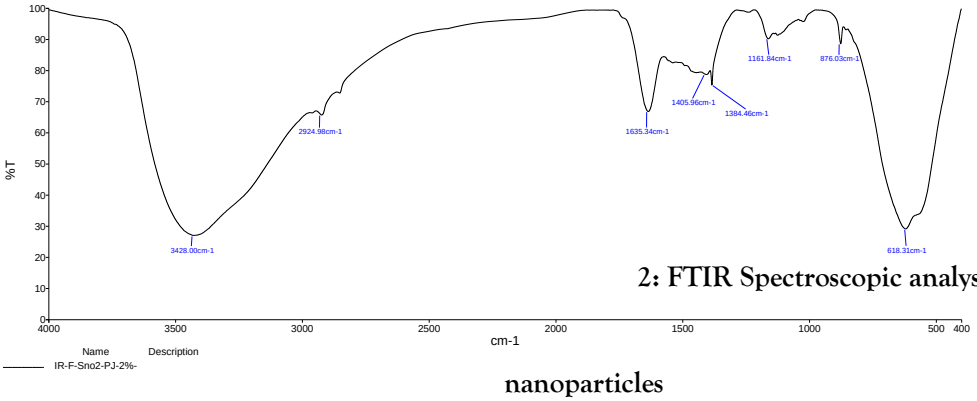

Figure 2: FTIR Spectroscopic analysis of 2% F-doped SnO_2 nanoparticles

Scanning Electron Microscopical (SEM)

SEM analysis was carried out to understand the topology and the size of the NPs, which showed the synthesis of higher density polydispersed spherical NPs of various sizes that crystalline nature of the nanoparticles (Figure 3). Most of the nanoparticles gathered and only a little of them were polydispersed and spherical in shape, when observed under SEM. To find out the particle size of the nanoparticles using histograms plotted on the obtained data to study the particle size distribution using ImageJ software and the size of the nanoparticles ranged from 16 to 26nm and the average particle size was found to be 23.39 ± 8.60 nm (Figure 4).

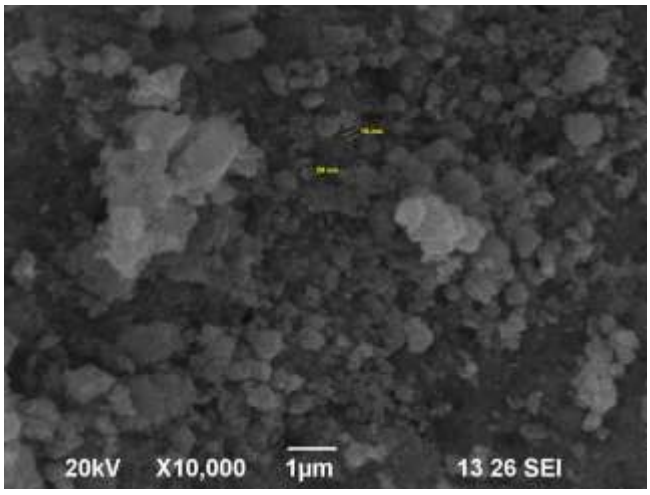

Figure 3: Scanning Electron Microscopical (SEM) analysis of F-doped SnO_2 nanoparticles

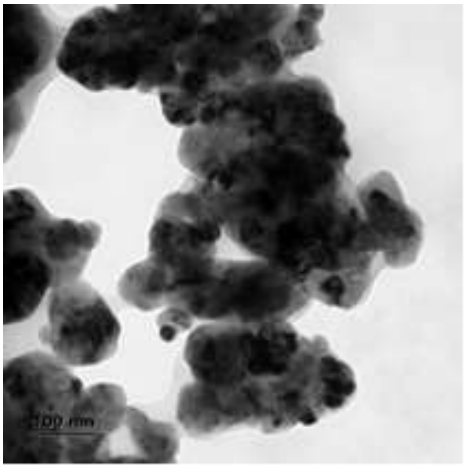

Figure 4: Histogram of showing particle size distribution of F-doped SnO_2 nanoparticles

TEM Analysis

TEM provides improved spatial resolution compared with SEM and enables a more in-depth analysis of nanoparticles. The TEM images of fluorine doped tin oxide nanoparticles are shown in Figure 5. It is observed that the morphology of nanoparticles is often polydispersed and spherical in shape. The close examination of the size of FTO particles reveals that it falls in nanoscale, and these particles are found to be agglomerated. In general, agglomeration occurs in the case of nanoparticles very easily because the surface forces such as Vander-Waals forces, capillary forces and electrostatic forces could overcome only against gravitational and inertial forces for particles in this size range (Pugh and Bergstro¨m, 1994). Similar reports observed in Senthilkumar et al. (2010).

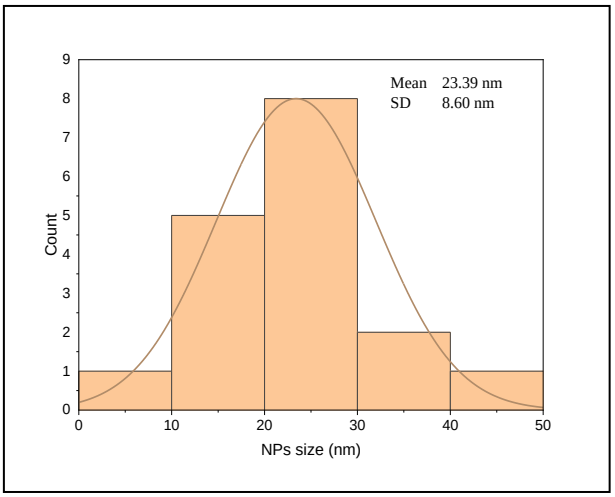

Figure 5: Transmission Electron Microscopical (TEM) analysis of F-doped SnO_2 nanoparticles

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Antimicrobial activity of F-doped SnO_2 nanoparticles

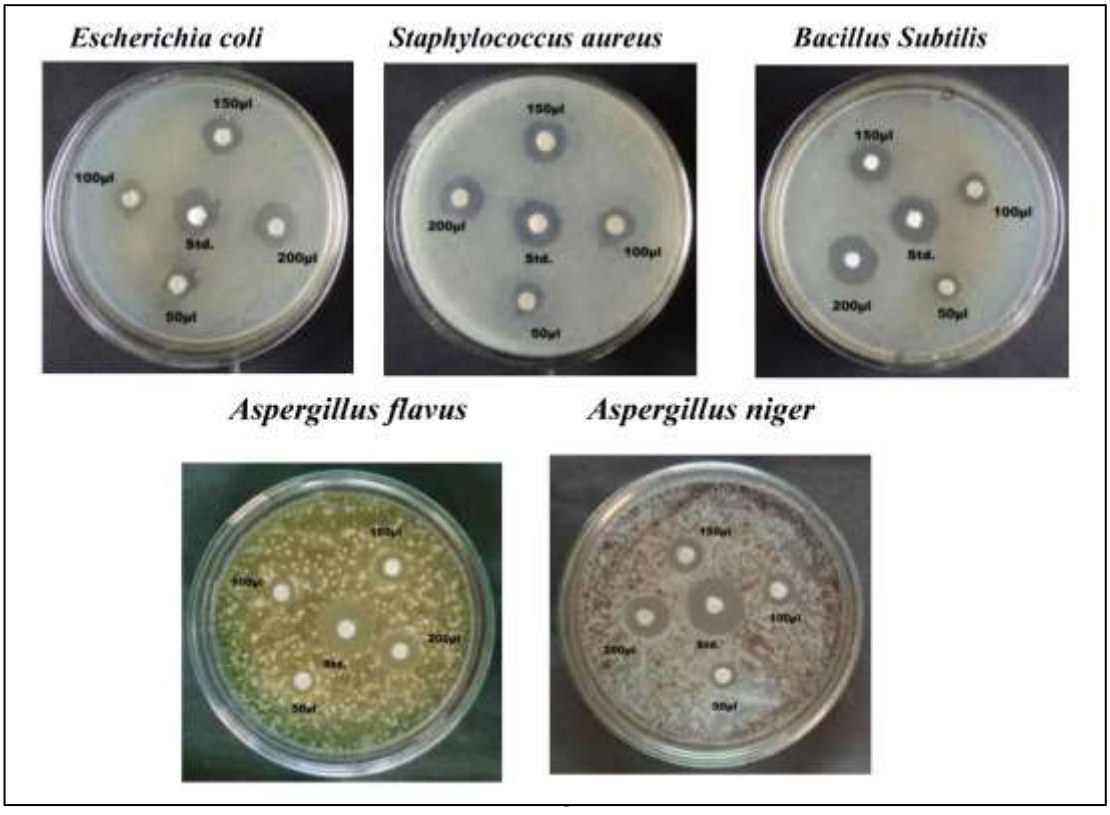
The 2% F-SnO_2 nanoparticles tested against bacteria (*Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis*) and fungi (*Aspergillus flavus* and *Aspergillus niger*) (Figure 6). The maximum zone of inhibition of 2 % F-SnO_2 nanoparticles against bacteria *Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis* showed 10, 11 and 12 nm at the concentration of 200µl while the minimum was 4, 4 and 3 nm at the concentration of 50µl. The maximum zone of inhibition of 2 % F-SnO_2 nanoparticles against fungi *Aspergillus flavus* and *Aspergillus niger* showed 11 and 9 nm at the concentration of 200µl while the minimum was 3 and 3 nm at the concentration of 50µl. The zone of inhibition was increased with increase the concentrations were noticed. The antimicrobial activity of 2 % F-SnO_2 nanoparticles are nearest to the standard (Chloramphenicol and Clotrimazole) were observed (Table 1 and Plate 1). Among the various bacteria and fungal strains, the antimicrobial property of 2 % F-SnO_2 nanoparticle has potential against *Bacillus Subtilis* and *Aspergillus flavus*.

Table 1: Antimicrobial activity of F-SnO_2 nanoparticles against Bactria and fungal strains

S.No.	Microorganisms	Zone of Inhibition (mm in diameter)					
		Control	Standard*	50µl	100µl	150µl	200µl
	Bacteria						
1	*Bacillus Subtilis*	-	13	3	6	8	12
2	*Staphylococcus aureus*	-	12	4	7	9	11
3	*Escherichia coli*	-	11	4	6	7	10
	Fungi						
1	*Aspergillus flavus*	-	14	3	6	8	11
2	*Aspergillus niger*	-	16	3	5	7	9

*Chloramphenicol (30 mcg); Clotrimazole (mcg/disc)

Figure 6: Antimicrobial activity of FTO against bacteria and fungal strains



Nanoparticles have attracted much interest because of their unique physical and chemical properties, which originate from the high area to volume ratio and elevated quantity of surface atoms. In fact, as the diameter decreases, the available surface area of the particle itself dramatically increases, and, consequently, there is an increase over the original properties of the corresponding bulk material. This feature makes nanoparticles superior and exceptional candidates for biomedical applications as a variety of biological processes occur at the nanometer level (Sharma et al. 2009; Prabhu and Poulose 2012). Thus, nanoparticles hold incredible potential in various biomedical uses including antibacterial agent. Recently, many studies have demonstrated that different metal oxide nanoparticles exhibit biocidal action against bacteria and fungi. The antimicrobial activity of the nanoparticles is known to be a function of the surface area in contact with the microorganisms (Franci et al. 2015; Chiriac et al. 2016).

In the last years, bacterial resistance to bactericides and antibiotics has increased. Many organic antimicrobial agents are toxic to humans and other animals, furthermore, can be the cause of different allergic reactions (Rajawat and Qureshi 2012; Hossain et al. 2015). In order to solve this problem, inorganic antibacterial agents have attracted interest for bacteria control, due to their good safety, sustainability, heat resistance, and improved stability under harsh processing conditions. Currently, nanotechnology provides a sound platform for adjusting the physicochemical properties of numerous materials to generate effective antimicrobials (Beyth *et al.* 2015). Silver (Ag), gold (Au), titanium oxide (TiO_2), copper oxide (CuO), zinc oxide (ZnO), and manages oxide (MnO) are the principal metal nanoparticles (NPs) used as antibacterial agents once their potent antibacterial effects are well known (Zhang 2015).

The antimicrobial activities of and F doped SnO_2 nanoparticles (F-SnO_2) were studied against bacteria and fungi using the standard disc diffusion method. In the present study 2% F doped SnO_2 nanoparticles tested against bacteria (*Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis*). The antibacterial activity was increased dose-dependent manner. Experimental results demonstrated that 2% F-doped tin oxide nanoparticles (F doped SnO_2) exhibited the maximum antibacterial effect compared to standard. Similar reports agreed by Algethami et al. (2023) who examined the antibacterial activity against *Escherichia coli* and CeO_2–SnO_2 composite nanofibers depicted excellent activity. Another study Assd et al., (2023) who showed that the most effective inhibitor of both Gram-negative and Gram-positive bacteria is SnO_2 nanoparticles produced.

Metal oxide nanoparticles tend to have a negative zeta potential, which easily interacts with this surface potential according to the electrostatic force equilibrium. This significant bactericidal activity was due to the release of fluorine ions and Sn from F-doped SnO_2 nanoparticles, and the permeation of the bacterial cell membrane by these ions. Ions can be released from the interaction between SnO_2 NPs with the cell wall leading to the generation of reactive oxygen species (ROS) on the surface of the nanoparticles. The permeation of ions was possible due to the attraction of their positive charges to the negatively-charged cell wall. The binding of these ions destroyed the bacterial cell membrane. In addition, metal ions are involved in cross-linkage of nucleic acid strands by binding with DNA molecules of bacteria. This produces a disorder in the DNA structure, leading to protein denaturation and complete destruction of the bacterial cell (Reddy et al., 2007; Wang et al., 2015; Ahmad et al., 2017). The bactericidal effect of metal nanoparticles has been attributed to their small size and high surface to volume ratio, which allows them to interact closely with microbial membranes and is not merely due to the release of metal ions in solution (Ruparelia et al. 2008)

Fungi, which comprises diverse groups with different morphologies, such as unicellular yeasts and multicellular organisms. One promising solution as an antifungal agent is the use of nanoparticles (NPs). Manystudies investigate this field of nanotechnology, but the

mechanisms of action involved in NPs use as an antifungal agent (Babele et al., 2018). In the present study 2% F doped SnO_2 nanoparticles tested against fungi (*Aspergillus flavus* and *Aspergillus niger*). Present study agreement with Jebril et al., (2020) who reported that metal nanoparticles synthesized with *M. charantia* and *P. guajava* extracts showed good antifungal capacity in concentrations of 20 ppm, inhibiting the growth of mycelium in fungi such as *A. niger*, *A. flavus*, and *F. oxysporum*.

Metal nanoparticle mediated fungal cell toxicity occurs through many mechanisms, including cell wall damage and change (such as ergosterol synthesis inhibition), gene regulation, interaction with reproductive structures and hyphae, and ROS production, causing cascades of damages such as lipid peroxidation and mitochondrial damage. This multi-faceted attack makes NPs an avenue worth investigating as potential future antifungal treatments (Slavin and Bach, 2022).

CONCLUSION

The results of this study indicate that although the synthesized 2% F doped SnO_2 nanoparticles possess potent and desirable biological properties such as antimicrobial (Bacteria and fungi) activity, This is due to the large surface and smaller particle size of F-doped nanoparticles. Thus, the synthesized nanoparticles hold enormous potential for use in the cosmetic, nutraceutical and pharmaceutical industries.

REFERENCES

Ahmad W, Khan SA, Munawar KS, Khalid A, Kanwal S. Synthesis, characterization and pharmacological evaluation of mixed ligand-metal complexes containing omeprazole and 8-hydroxyquinoline. Trop J Pharm Res 2017; 16(5): 1137-1146.

Algethami, J.S.; Hassan, M.S.; Amna, T.; Sheikh, F.A.; Alhamami, M.A.M.; Seliem, A.F.; Faisal, M.; Kim, H.Y. Nanotextured CeO_2-SnO_2 Composite: Efficient Photocatalytic, Antibacterial, and Energy Storage Fibers. Nanomaterials 2023, 13, 1001

Ashe B (2011). A Detail investigation to observe the effect of zinc oxide and Silver nanoparticles in biological system, (Doctoral dissertation).

Assd. A AL Hadi, 2 Abbas M Ali AL-Kifaie. Antibacterial by use SnO_2 Nanoparticle by Hydrothermal Method. Int. j. adv. multidisc. res. stud. 2023; 3(3):1003-1006

Awoyinka, O.A., Balogun I.O. and Ogunnow, A.A. (2007). Phytochemical screening and *in vitro* bioactivity of *Cnidoscolus aconitifolius* (Euphorbiaceae). *J. Med. Plant Res*, 1: 63-95.

Babele, P.K.; Thakre, P.K.; Kumawat, R.; Tomar, R.S. Zinc oxide nanoparticles induce toxicity by affect-ing cell wall integrity pathway, mitochondrial function and lipid homeostasis in Saccharomyces cere-visiae. Chemosphere 2018, 213, 65–75.

Beyth N, Houri-Haddad Y, Domb A, Khan W, Hazan R. Alternative antimicrobial approach: Nanoantimicrobial materials. Evid-Based Complement Altern Med. 2015;2015:246012.

Chiriac V, Stratulat DN, Calin G, Nichitus S, Burlui V, Stadoleanu C, Popa M. Antimicrobial property of zinc based nanoparticles. IOP Conf Ser: Mater Sci Eng. 2016;133:012055.

Deotale V, Mendiratta DK, Raut U, Narang P. Inducible clindamycin resistance in Staphylococcus aureus isolated from clinical samples. Ind J Med Microbiol. 2010;28:124.126.

Franci G, Falanga A, Galdiero S, Palomba L, Rai M, Morelli G, Galdiero M. Silver nanoparticles as potential antibacterial agents. Molecules. 2015;20:8856–74

Gebreslassie Y.T. , Gebretnsae Green H.G. Green and Cost-Effective Synthesis of Tin Oxide Nanoparticles: (2021).A Review on the Synthesis Methodologies, Mechanism of Formation, and Their Potential Applications Nanoscale Res. Lett., 16 (4),1-20.

Hossain KMZ, Patel U, Ahmed I. Development of microspheres for biomedical applications: a review. Prog Biomater. 2015;4:1.

Jebril, S.; Ben Jenana, R.K.; Dridi, C. Green synthesis of silver nanoparticles using Melia azedarach leaf extract and their antifungal activities: In vitro and in vivo. Mater. Chem. Phys. 2020, 248, 122898.

Jiale Huo ORCID logoab, Yaofang Zhang *ab, Weimin Kang ORCID logoac, Yan Shen ab, Xiang Li ab, Zirui Yan ab, Yingwen Pan ab and Wei Sun. Synthesis of F-doped materials and applications in catalysis and rechargeable batteries. Nanoscale Adv., 2023, 5, 2846-2864

Kar, S. and Kundoo, S. (2015) Synthesis and Characterization of Pure and Fluorine Doped Tin-Oxide Nano-Particles by Sol-Gel Methods. International Journal of Science and Research, 1, 39

Kim, C.-Y. and Riu, D.-H. (2011) Texture Control of Fluorine-Doped Tin Oxide Thin Film. Thin Solid Films, 519, 3081-3085.

Lisnic P., L. Hrostea, L. Leontie, M. Girtan. Fluorine-Doped SnO_2 Thin Films in Solar Cell Applications. Morphological,Optical and Electrical Properties. Arch. Metall. Mater. 68 (2023), 2, 483-490

Matthews L, Kanwar RK, Zhou S, Punj V, Kanwar JR. Applications of nanomedicine in antibacterial medical therapeutics and diagnostics. Open Trop Med J. 2010;3:1.9.

Mukherjee A, Sadiq M, Prathna TC, Chandrasekaran N. Antimicrobial activity of aluminium oxide NPs for potential clinical applications. In: M.endez-Vilas A, editor. Science against microbial pathogens communicating current research and technological advances. Badajoz, Spain: FORMATEX; 2011. p. 245.251.

NCCLS. (1993) National Committee for Clinical Laboratory Standards. Performance standards for antimicrobial disc susceptibility tests. PA: NCCLS Publications 25.

Prabhu S, Poulose EK. Silver nanoparticles: mechanism of antimicrobial action, synthesis, medical applications, and toxicity effects. Int Nano Lett. 2012;2:32.

Pugh RJ, Bergstro¨m L (1994) Surface and colloid chemistry in advanced ceramic processing. Marcel Dekker, New York, p 273

Rajawat S, Qureshi MS. Comparative study on bactericidal effect of silver nanoparticles, synthesized using green technology, in combination with antibiotics on Salmonella typhi. J Biomater Nanobiotechnol. 2012;3:480–5.

Rasmussen JW, Martinez E, Louka P and Wingett DG (2010). Zinc oxide nanoparticles for selective destruction of tumor cells and potential for drug delivery applications. EODDAW, 7(9): 1063-1077.

Reddy KM, Feris K, Bell J, Wingett DG, Hamley C, Punnoose A. Selective toxicity of zinc oxide nanoparticles to prokaryotic and eukaryotic system. Appl Phys Lett 2007; 90: 2139021-2139023,

Ruparelia JP, Chatterjee AK, Duttagupta SP, Mukherji S. Strain specificity in antimicrobial activity of silver and copper nanoparticles. Acta Biomater. 2008;4:707–16.

Senthilkumar V. Vickraman P. Ravikumar R.. Synthesis of fluorine doped tin oxide nanoparticles by sol-gel technique and their characterization. J Sol-Gel Sci Technol (2010) 53:316–321.

Sharma VK, Yngard RA, Lin Y. Silver nanoparticles: green synthesis, and their antimicrobial activities. Adv Colloid Interf Sci. 2009;145:83–96.

Slavin, Y.N.; Bach, H. Mechanisms of Antifungal Properties of Metal Nanoparticles. Nanomaterials 2022, 12, 4470.

Sobha K, Surendranath K, Meena V, Jwala KT, Swetha N, Latha KSM. Emerging trends in nanobiotechnology. J Biotechnol Mol Biol Rev. 2010;5:001.012.

Van Tran, T., Turrell, S., Eddafi, M., Capoen, B., Bouazaoui, M., Roussel, P., Berneschi, S., Righini, G., Ferrari, M., Bhaktha, S.N.B., Cristini, O. and Kinowski, C. (2010)

Investigations of the Effects of the Growth of SnO_2 Nanoparticles on the Structural Properties of Glass-Ceramic Planar Waveguides Using Raman and FTIR Spectroscopies. Journal of Molecular Structure, 976, 314-319.

Wang Y, Zhao X, Duan L, Wand F, Niu H, Guo W, Ali A. Structure luminescence and photocatalytic activity of Mn-doped ZnO nanoparticles prepared by auto combustion method. Mat Sci Semi Process 2015; 29: 372-379.

Zhang X. Gold nanoparticles: recent advances in the biomedical applications. Cell Biochem Biophys. 2015;72:771–5.

Zhang Y, Ram MK, Stefanakos EK and Goswami, DY (2012). Synthesis, characterization, and applications of ZnO nanowires. J. Nanomater., Article ID 624520.

Zhang, B., Tian, Y., Zhang, J.X. and Cai, W. (2011) The Role of Oxygen Vacancy in Fluorine-Doped SnO_2 Films. Physica B: Condensed Matter, 406, 1822-1826.