BUSITEMA UNIVERSITY
Pursuing Excellence

P.O. Box 236, Tororo, Uganda
Gen: +256 - 45 444 8838
Fax: +256 - 45 4436517
Email: info@adm.busitema.ac.ug

www.busitema.ac.ug

A REVIEW ON ZINC AND ZINC OXIDE NANOPARTICLES; BIOSYNTHESIS, CHARACTERIZATION AND APPLICATIONS.

BY

NADUNGA SANDRA

BU/UP/2018/3482

A RESEARCH PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF CHEMISTRY TOWARDS FULFILLMENT OF THE REQUIREMENTS LEADING TO THE AWARD OF A BACHELOR'S DEGREE OF SCIENCE EDUCATION OF BUSITEMA UNIVERSITY

MAY-2022

DECLARATION

I NADUNGA SANDRA, hereby declare that this report is an original review of work presented by different researchers on the topic ZINC AND ZINC OXIDE NANOPARTICLES; BIOSYNTHESIS, CHARACTERIZATION AND APPLICATIONS. All the work refered to has been properly acknowledged according to the Busitema University guidelines on research and projects.

Signature…….

Date……../……/……

NADUNGA SANDRA.

This review has been submitted to the department of chemistry with the approval of my supervisor(s).

08.05.2022

Signature: ……. Date: …….

Dr. Andima Moses

Senior Lecturer

Department of chemistry

mandima@sci.busitema.ac.ug

+256(0)777-058-371

DEDICATION.

I dedicate my piece of work to many of my friends, a special feeling of gratitude to my loving parents, Mr. TANDIGA ROBERT AND NAMBOZO TOPISTER whose words of encouragement and endless efforts have enabled me reach to this point. My dear brothers and sisters whose words of encouragement never left me the same. And to all my family members that supported me financially and emotionally

This research project review paper is also dedicated to all the Chemistry lecturers of Busitema University, Nagongera campus for laboring with me in an appropriate way and bringing me up morally upright in this profession. Special appreciation is directed to my supervisor DR. ANDIMA MOSES in particular for his efforts towards my project research, he has supported me throughout the process and I will always appreciate all he has done, especially guidance that helped me develop my technological skills, thinking skills and creativity.

ACKNOWLEDGEMENT

First and foremost, I thank the Almighty God for his love, protection, guidance, mercy and provision throughout the entire course of my studies. I with great pleasure appreciate the assistance rendered to me by my dear supervisor Dr. Andima Moses, the commitment and his words of encouragement to me, his guidance and presence at all times when needed during the course of my research. Special thanks also goes to all the lecturers of Busitema University, Chemistry Department, Dr. Kamoga Omar, Dr. Oriko Richard Owor, Mr. Egor Moses, Mr. Oyege Ivan, and Mr. Musagala Peter, Dr.Kigozi Moses and the lab technician madam Nakijoba Lydia for their sincere advice, guidance, sacrifices, comments and recommendations throughout the development of my research work.

I also want to thank my dearest friends Diiri James Emmanuel, Nnakazzi Mariam and Kirimwira Ivan for all their endless support rendered towards my research and not forgetting all my class mates in the Chemistry class and the BUBPAC family

Table of Contents

List of figures.

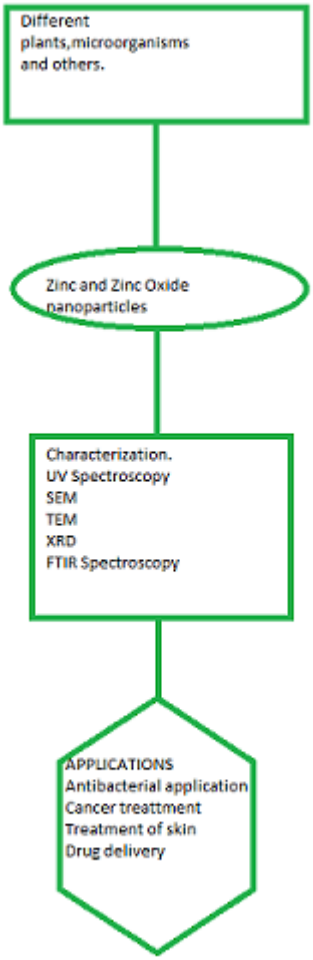
ABSTRACT.

Nanoparticles are particles of very small size from 1nm to 1000nm but of great importance. Zinc oxide nanoparticles are widely applied in various fields such as medicine, food packing, cosmetics, sun screening lotions and many others due to their properties.

ZnO-NPs show excellent antibacterial properties because of its high surface area as a result of their small particle size and therefore high surface activity. Zinc Oxide is highly bio-safe with photo-oxidizing and photocatalysis effect on several biological species.

A number of infections and diseases caused by several bacteria have for long become hard to cure because of resistance of the pathogens to drugs and therefore antibacterial suture is by far a solution to infections like surgicalsteinfection (SSI), which is an infection mainly caused by (S.aureu) and (E.coli) and to a number of unique properties of nano-zinc oxide, the nanoparticles of Zinc oxide are excellent antibacterial agents in antibacterial suture since ZnO-NP coated sutures have a tremendous bacterial inactivation and also in many other ways. ZnO-NPs were synthesized and have an average size of around 112nm.

Zinc oxide nanoparticles have proved to have a high antibacterial action against bacteria S. aureus and E. coli and their activity can last up to five days. The ZnO NP-coated exhibited a high performance on bacterial inactivation



Keywords. Antibacterial activity, ZnO-NPs, Biosynthesis, Toxicity, Eco-friendly, Biomedical

Abbreviations.

Word	Meaning
NPs	Nanoparticles
Zn	Zinc
ZnO	Zinc Oxide
Nm	Nanometer
UV	Ultraviolet

1.0. INTRODUCTION.

1.1. Background.

Nanotechnology is a science that deals with research and innovation concerned with development of materials that are so tiny and cannot be further simplified. It is the study and use of particles with dimension ranging from 1 to 1000 nm. Therefore nanoparticles are very small particles of size ranging from 1nm to 1000 nm (Chaudhary et al., 2019)(S. Tabrez, J. Musarrat, 2016).

Basing on their size ranging from small size to bulk, nanoparticles have different properties, leading to a wide range of application in many fields such as in electronics, energy, environment and health and many others.(S. Tabrez, J. Musarrat, 2016)

Nanoparticles can be synthesized in a number of ways which include, chemical, physical and biological. Physical and chemical methods of synthesis of nanoparticles are not largely applied because they require a lot of expenses and some of the materials formed are toxic making bio synthesis more efficient since the method is less toxic and cost friendly. (Chaudhary et al., 2019)

Biosynthesis of Nanoparticles uses plant extract or microorganisms. Synthesis from microorganisms is classified into intracellular and extracellular synthesis which involves mixture of specific ions of interest for example gold, silver, zinc, copper and many others with the extract. Zinc oxide and zinc nanoparticles can also be synthesized from different biomaterials including plant and microbial extracts.(Chaudhary et al., 2019)(K. Elumalai, 2015)

Plants such as Aloe barbadensis, Parthenium hysterophorus, Borassus flabellifer fruit, Plectranthus amboinicus have been used to produce zinc and zinc oxide nanoparticles.(V. Nachiyar, S. Sunkar, 2015). Among microbes, bacteria and fungi or their extracts have also been utilized to synthesize nanoparticles either intracellularly or extracellularly.(A. Yadav, K. Kon, G. Kratosova, N. Duran, A. P. Ingle, 2015)(Agarwal et al., 2017b)(Yusof et al., 2019)

Various techniques are used to measure properties of these nanoparticles and they include Ultra violet (UV) Spectroscopy, Atomic Absorption Spectroscopy, and Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Fourier Transformed Infrared (FTIR)

spectroscopy, Zeta- sizer Nano ZS90 X-ray Diffraction (XRD) and many others. Biosynthesized Zinc Oxide nanoparticles are highly crystalline and the average crystallite size of the nanoparticles is about 17 nm. These nanoparticles have tremendous UV absorption and a strong yellow-orange color emission at room temperature.(Hidayat Mohd Yusof1, Nor'Aini Abdul Rahman , Rosfarizan Mohamad, 2020) (Alamdari & , Morteza Sasani Ghamsari , Chan Lee , Wooje Han , Hyung-Ho Park * , Majid Jafar Tafreshi, 2020)

Biosynthesized Zinc and Zinc oxide nanoparticles show excellent antimicrobial activity against a number of bacteria and fungi making them a potential application in medicine and the activity of this nanoparticles is based on properties such as size, shape, concentration and exposure time to the bacterial cell.(Agarwal et al., 2017a)(Chaudhary et al., 2019)

According to literature, zinc oxide nanoparticles are applied in animal and poultry feeds as a feed supplement and there is evidence that their application leads to improved growth, productivity, health and an enhancement in Antioxidation.(Yusof et al., 2019)

In poultry, integration of these nanomaterials in feeds improves the egg quality. (Hidayat Mohd Yusof1, Nor'Aini Abdul Rahman , Rosfarizan Mohamad, 2020). Zinc oxide nanoparticles are also applied in cosmetics, food packaging and sunscreen lotions since they have ability to absorb toxic radiations and prevent bacterial growth in food**.** (Ibrahim Kahramano ˘glu, 2019)(Alamdari & , Morteza Sasani Ghamsari , Chan Lee , Wooje Han , Hyung-Ho Park * , Majid Jafar Tafreshi, 2020)

Zinc is an important element in all living organisms leading to sufficient evidence that zinc oxide nanoparticles have a great potential in various biological applications preferably antimicrobial activity. Owing to the fact that these nanoparticles have the tremendous ability to inhibit the growth of many pathogens, nanoparticles are being used as an antibiotics. (Chaudhary et al., 2019).

Upon encounter with bacteria, the nanoparticles first damage the cell wall which enables them to penetrate and accumulate in the membrane of the cell which eventually causes ultimate death by disorganizing the metabolic activity of the microbe. In addition to the above, zinc is a trace mineral element of great importance that plays vital roles in many physiological processes in the body hence integration of its nanoparticles in feeds increases its absorption and use in the

body.(L. Fu, 2015) (S. Ambika, 2015a)(Amna Sirelkhatim, Shahrom Mahmud & Mohamad, Noor Haida Mohamad Kaus, Ling Chuo Ann, Siti Khadijah Mohd Bakhori, 2015)

1.2 The Problem.

Microorganisms such as bacteria, fungi, viruses and parasites are the cause of most illnesses in human beings. These microbes change in ways that render the medicine used to cure the diseases ineffective hence resulting into resistance to conventional drugs. This is a major concern since a resistant infection that spreads to others may kill the infected individuals and causes huge costs to the infected persons and the society at large.

Antimicrobial resistance refers to resistance of different types of microorganisms and involves resistance to antibacterial, antiviral, antiparasitic and antifungal drugs., Resistance occurs naturally but can also be caused by inappropriate use of medicines. For example, Malaria is one of the leading causes of death in tropical Africa but the disease has become increasingly resistant to common antimalrial drugs..

Mycobacterium tuberculosis is a bacterial infection treated with use of different antibacterial drugs but some bacteria have developed resistance to the two most potent TB drugs; Rifampicin and isoniazid. The Enterococi commonly found in the colon have increasingly developed resistance to vanomycin. Therefore due to increasing resistance of microbes to first and second line antimicrobials, there is aworld wide call for development of alternative therapies treatment of most microbial infections.

Metals and metal ions play many important physiological functions in the body. In particular transition metal complexes exhibit unique and interesting properties such as changing oxidation states and the ability to form specific interactions with other biomolecules (V. Nachiyar, S. Sunkar, 2015)(Chaudhary et al., 2019).

Thus transition metals and their complexes have been used for the development of drugs with promising pharmacological applications and may offer unique therapeutic opportunities (S. Rajeshkumar, C. Malarkodi, M. Vanaja, 2016)(A.S. Hameed, C. Karthikeyan, A.P. Ahamed, N. Thajuddin, N.S. Alharbi, 2016).

It was shown that some metal-drug complexes are more potent as compared to pure drug. Towards this hypothesis, the interactions of some antibiotics with transition metals have been

studied.(Mirzaei & Darroudi, 2017). Among them, zinc is known to exhibit antibacterial activity.(Chaudhary et al., 2019). Zinc oxide (ZnO) nanoparticles have been demonstrated to be even more efficient along with reduced human toxicity. (Alamdari & , Morteza Sasani Ghamsari , Chan Lee , Wooje Han , Hyung-Ho Park * , Majid Jafar Tafreshi, 2020)

The focus of this review therefore is on biosynthesis of zinc and zinc oxide nanoparticles, characterization and the biomedical applications of the nanoparticles. This review is divided into four parts; the first part discusses the methods of synthesis of the nanoparticles focusing on the biosynthetic methods while highlighting the examples, advantages and disadvantages.

In section two, the general methods of characterization are discussed and particular attention is given to the basic principle of the methods used for characterization. Section three focusses on the biomedical applications of the nanoparticles. In the last section, general discussions and future prospects are discussed. This research will help to solve the problem of drug resistance of bacteria and fungi since nanoparticles show great importance.

2.0 METHODOLOGY

Data for this research was obtained from scientific databases using googlescholar search engine using a combination of key words such as; “zinc nanoparticles”, “zinc oxide nanoparticles” Zinc AND nanoparticles AND synthesis, Zinc oxide AND nanoparticles AND Synthesis, Zinc AND Zinc oxide AND Nanaoparticles AND application. Articles that matched the key words were retrieved and studied for content appropriateness. Artilces that described exactly the key words were studied in detail to compile this report.

Among these articles, articles published between 2010 and 2021 and cited more than 80 times. were considered and these were thoroughly examined and data is presented in the following sections.

2.1. Synthesis.

By using the key words “zinc and zinc oxide nnanoparticles” and “synthesis” articles were searched on google scholar

These explained different methods used to in the synthesis of zinc and zinc oxide nanoparticles but since many articles were accessed, only articles that were published between 2010 and 2021 were considered, amongst these, articles that received more than 80 citations and whose data

5.0 REFERENCES

1. A. Yadav, K. Kon, G. Kratosova, N. Duran, A. P. Ingle, and M. R. (2015). Fungi as an efficient mycosystem for the synthesis of metal nanoparticles. *Biotechnology Letters*, *37*(11), 2099–2120.

2. A.S. Hameed, C. Karthikeyan, A.P. Ahamed, N. Thajuddin, N.S. Alharbi, S. A. A. harb. (2016). In vitro antibacterial activity of ZnO and Nd doped ZnO nanopar_ticles against ESBL producing Escherichia coli and Klebsiella pneumoniae. *Sci. Rep*, *6*.

3. Agarwal, H., Kumar, S. V., & Rajeshkumar, S. (2017a). Resource-Efficient Technologies Review article A review on green synthesis of zinc oxide nanoparticles – An eco-friendly approach. *Resource-Efficient Technologies*, *3*(4), 406–413. https://doi.org/10.1016/j.reffit.2017.03.002

4. Agarwal, H., Kumar, S. V., & Rajeshkumar, S. (2017b). Resource-Efficient Technologies Review article A review on green synthesis of zinc oxide nanoparticles – An eco-friendly approach. *Resource-Efficient Technologies*, *3*(4), 406–413. https://doi.org/10.1016/j.reffit.2017.03.002

5. Alamdari, S., & , Morteza Sasani Ghamsari , Chan Lee , Wooje Han , Hyung-Ho Park * , Majid Jafar Tafreshi, H. A. and M. H. M. A. (2020). applied sciences Preparation and Characterization of Zinc Oxide Nanoparticles Using Leaf Extract of Sambucus ebulus. *Applied Sciences*, *10*, 1–19. www.mdpi.com/journal/applsci

6. Amna Sirelkhatim, Shahrom Mahmud, A. S., & Mohamad, Noor Haida Mohamad Kaus, Ling Chuo Ann, Siti Khadijah Mohd Bakhori, H. H. D. (2015). Review on Zinc Oxide Nanoparticles : Antibacterial Activity and Toxicity Mechanism. *Nano-Micro Letters*, *7*(3), 219–242. https://doi.org/10.1007/s40820-015-0040-x

7. Chaudhary, A., Kumar, N., Kumar, R., & Kumar, R. (2019). Antimicrobial activity of zinc oxide nanoparticles synthesized from Aloe vera peel extract. *SN Applied Sciences*, *1*(1), 1–9. https://doi.org/10.1007/s42452-018-0144-2

8. Cuevas, R., Durán, N., Diez, M. C., Tortella, G. R., & Rubilar, O. (2015). Extracellular Biosynthesis of Copper and Copper Oxide Nanoparticles by Stereum hirsutum , a Native White-Rot Fungus from Chilean Forests. *Journal of Nanomaterials*, *2015*, 1–7.

http://dx.doi.org/10.1155/2015/789089%0A

9. Dragan, N. A., & Silva, C. De. (2016). *Synthesis, Characterization, and Antimicrobial studies of Manganese (II) and Europium (III) Metal Ion doped Zinc Oxide Nanoparticles for potential clinical applications.* Western Carolina University.

10. F.T. Thema, E. Manikandan, M.S. Dhlamini, M. M. (2015). Green synthesis of ZnO nanoparticles via Agathosma betulina natural extract. *Mater. Lett*, *161*, 124–127. https://doi.org/10.1016/j.matlet.2015.08.052.

11. Ghamba, P., Balla, H., Goje, L., Halidu, A. and Dauda, M. (2014). In Vitro Antimicrobial Activities of Vernonia amygdalina on Selected Clinical Isolates. *International Journal of Current Microbiology and Applied Sciences*, *3*(4), 1103–1113.

12. Haritha Meruvu , Meena Vangalapati *, S. C. C. and S. R. B. (2011). Stnthesis and Characerization of Zinc Oxide Nanoparticlesand its Antimicrobial Activity against Bacillus Subtilis and Escherichia Coli. *RASAYAN J. Chem*, *4*(1), 217–222.

13. Hidayat Mohd Yusof1, Nor'Aini Abdul Rahman , Rosfarizan Mohamad, U. H. Z. & A. A. S. (2020). Biosynthesis of zinc oxide nanoparticles by cell - biomass and supernatant of Lactobacillus plantarum TA4 and its antibacterial and biocompatibility properties. *Scientific Reports*, *10*, 1–13. https://doi.org/10.1038/s41598-020-76402-w

14. Ibrahim Kahramano ˘glu, C. C. (2019). Chemical Constituents, Antimicrobial Activity, and Food Preservative Characteristics of Aloe vera Ge. *Agronomy*, 1-18.

15. K. Ali, S. Dwivedi, A. Azam, Q. Saquib, M.S. Al-said, A.A. Alkhedhairy, et a. (2016a). Aloe vera extract functionalized zinc oxide nanoparticles as nanoantibiotics against multi-drug resistant clinical bacterial isolates. *J. Colloid Interface Sci*, *21*(3), 145–156.

16. K. Ali, S. Dwivedi, A. Azam, Q. Saquib, M.S. Al-said, A.A. Alkhedhairy, et al. (2016b). Aloe vera extract functionalized zinc oxide nanoparticles as nanoantibiotics against multi-drug resistant clinical bacterial isolates. *J. Colloid Interface Sci*, *472*, 145–156.

17. K. Elumalai, S. V. (2015). Green synthesis, characterization and antimicro_bial activities of zinc oxide nanoparticles from the leaf extract of Azadirachta indica. *Appl. Surf. Sci*, *345*, 329–336.

18. L. Fu, Z. F. (2015). Plectranthus amboinicus leaf extract-assisted biosynthesis of ZnO nanoparticles and their photocatalytic activity. *Ceram. Int*, *41*, 2492–2496.

19. M. Anbuvannan, M. Ramesh, G. Viruthagiri, N. Shanmugam, N. Kannadasan, pectrochim. (2015). Synthesis, characterization and photocatalytic activity of ZnO nanoparticles prepared by biological method. *Acta A Mol. Biomol. Spectrosc*, *143*, 304–308.

20. M. Anbuvannan, M. Ramesh, G. Viruthagiri, N. Shanmugam, N. K. (2015). Anisochilus carnosus leaf extract mediated synthesis of zinc oxide nanoparti_cles for antibacterial and photocatalytic activities. *Mater. Sci. Semicond.*, *39*, 621–628.

21. M. Ramesh, M. Anbuvannan, G. V. (2015). Green synthesis of ZnO nanopar_ticles using Solanum nigrum leaf extract and their antibacterial activity. *Spec_trochim. Acta A Mol. Biomol. Spectrosc*, *136*, 864–870.

22. M. Sundrarajan, S. Ambika, K. B. (2015). Plant-extract mediated synthesis of ZnO nanoparticles using Pongamia pinnata and their activity against pathogenic bacteria. *Adv. Powder Technol*, *26*, 1294–1299.

23. Mirzaei, H., & Darroudi, M. (2017). Zinc oxide nanoparticles_ Biological synthesis and biomedical applications. *Ceramics International*, *43*(1), 907–914. https://doi.org/10.1016/j.ceramint.2016.10.051

24. Mohammad Abdul Motaleb. (2011). *selected medicinal plants in Chittagong Hill Tracts* (pp. 1–128). Bangladesh Country Office.

25. P. Jamdagni, P. Khatri, J. S. R. (2016). Green synthesis of zinc oxide nanoparticles using flower extract of Nyctanthes arbor-tristis and their antifungal activity. *J. King Saud Univ. - Sci*.

26. P. Vanathi, P. Rajiv, S. Narendhran, S. Rajeshwari, P. K. S. M. R. (2014). Biosynthe_sis and characterization of phyto mediated zinc oxide nanoparticles: a green chemistry approach. *Mater. Lett*, *134*, 13–15.

27. P.E. Ochieng, E. Iwuoha, I. Michira, M. Masikini, J. Ondiek, P. G. (2015). Green route synthesis and characterization of ZnO nanoparticles using Spath_odea campanulata. *Int.*

J. Biochem. Phys, *23*, 53–61.

28. Quynh Mai Thi Tran, Hong Anh Thi Nguyen , Van-Dat Doan , Quang-Hieu Tran, and V. C. N. (2021). Biosynthesis of Zinc Oxide Nanoparticles Using Aqueous Piper betle Leaf Extract and Its Application in Surgical Sutures. *Journal of Nanomaterials*, 1–15. https://doi.org/10.1155/2021/8833864

29. R. Dobrucka, J. D. (2016). Biosynthesis and antibacterial activity of ZnO nanoparticles using Trifolium pratense flower extract. *Saudi J. Biol. Sc*, *23*, 517–523.

30. R. Zamiri, A. Zakaria, H.A. Ahangar, M. Darroudi, G. Zamiri, Z. Rizwan, G. P. C. D. (2013). The effect of laser repetition rate on the LASiS synthesis of biocompatible silver nanoparticles in aqueous starch solution. *Int. J. Nanomed.*, *8*, 233–244.

31. S. Ambika, M. S. (2015a). Antibacterial behaviour of Vitex negundo extract assisted ZnO nanoparticles against pathogenic bacteria. *J. Photochem. Photo_biol. B Bio*, *146*, 52–57.

32. S. Ambika, M. S. (2015b). Green biosynthesis of ZnO nanoparticles using Vitex negundo L. extract: spectroscopic investigation of interaction between ZnO nanoparticles and human serum albumin. *J. Photochem. Photobiol. B Biol*, *149*, 143–148.

33. S. Azizi, M.B. Ahmad, F. Namvar, R. M. (2014). Green biosynthesis and charac_terization of zinc oxide nanoparticles using brown marine macroalga Sargas_sum muticum aqueous extract. *Mater. Lett*, *38*, 275–277.

34. S. Jafarirad, M. Mehrabi, B. Divband, M. K.-N. (2016). Biofabrication of zinc oxide nanoparticles using fruit extract of Rosa canina and their toxic potential against bacteria: a mechanistic approach. *Mater. Sci. Eng. C.*, *59*, 296–302.

35. S. Mitra, P. Patra, S. Pradhan, N. Debnath, K.K. Dey, S. Sarkar, et al. (2015). Microwave synthesis of ZnO@mSiO2 for detailed antifungal mode of action study: under_standing the insights into oxidative stress. *Colloid Interface Sci*, *444*, 97–108.

36. S. Nagarajan, A.K. Kuppusamy. (2013). Extracellular synthesis of zinc oxide nanopar_ticle using seaweeds of gulf of Mannar. *J. Nanobiotechnology*, *11*.

37. S. Rajeshkumar, C. Malarkodi, M. Vanaja, G. A. (2016). Anticancer and en_hanced

antimicrobial activity of biosynthesizd silver nanoparticles against clinical Pathogens. *J. Mol. Struct*, *1116*, 165–173.

38. S. Tabrez, J. Musarrat, A. A. A. (2016). Colloids and surfaces B: biointerfaces countering drug resistance, infectious diseases, and sepsis using metal and metal oxides nanoparticles. *Current Status, Colloids Surf. B Biointerfaces*, *146*, 70–83.

39. Sharma, N., Jandaik, S., Kumar, S., & Chitkara, M. (2016). Synthesis , characterisation and antimicrobial activity of manganese- and iron-doped zinc oxide nanoparticles. *Journal of Experimental Nanoscience*, *11*(1), 54–71. https://doi.org/10.1080/17458080.2015.1025302

40. Stover, K. R., Travis King, S., & Robinson, J. (2012). Artemether-lumefantrina: Una Opción para la Malaria. *Annals of Pharmacotherapy*, *46*(4), 567–577. https://doi.org/10.1345/aph.1Q539

41. T. Bhuyan, K. Mishra, M. Khanuja, R. Prasad, A. V. (2015). Biosynthesis of zinc oxide nanoparticles from Azadirachta indica for antibacterial and photocat_alytic applications. *Mater. Sci. Semicond*, *32*, 55–61.

42. V. Nachiyar, S. Sunkar, P. P. (2015). Biological synthesis of gold nanoparticles using endophytic fungi. *Der Pharma Chem*, *7*, 31–38.

43. Weng, X.; Guo, M.; Luo, F.; Chen, Z. (2017). One-step green synthesis of bimetallic Fe/Ni nanoparticles by eucalyptus leaf extract: Biomolecules identification, characterization and catalytic activity. *Chem. Eng. J.*, *308*, 904–911.

44. Xie, Y., He, Y., Irwin, P. L., Jin, T., & Shi, X. (2011). Antibacterial Activity and Mechanism of Action of Zinc Oxide Nanoparticles against Campylobacter jejuni □. *APPLIED AND ENVIRONMENTAL MICROBIOLOGY*, *77*(7), 2325–2331. https://doi.org/10.1128/AEM.02149-10

45. Y. Qian, J. Yao, M. Russel, K. Chen, X. W. (2015). Characterization of green synthe_sized nano-formulation (ZnO-A. vera) and their antibacterial activity against pathogens, Environ. *Toxicol. Pharmacol*, *15*(1), 736–746.

46. Yusof, H. M., Mohamad, R., Zaidan, U. H., Aini, N., & Rahman, A. (2019). Microbial

synthesis of zinc oxide nanoparticles and their potential application as an antimicrobial agent and a feed supplement in animal industry : a review. *Journal of Animal Science and Biotechnology*, *10*, 1–22. https://doi.org/10.1186/s40104-019-0368-z%0A