GREEN SYNTHESIS OF BIOPOLYMER MEDIATED ZINC OXIDE NANOCOMPOSITES FOR ANTICANCER STUDY APPLICATION

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DEDICATION

This thesis is dedicated to my family, future wife and career

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ABSTRACT

The development of metal-oxide based composites can be drawn from advanced cancer treatment. For years, zinc oxide nanoparticles (ZnO-NPs) have gained great research attention for their potential applications in diverse areas including the medicine world. Chemicals are harmful to human health and the environment when used in the fabrication of various nanoparticles. This study aims to fabricate facile zinc oxide nanoparticles using carrageenan as a green stabilizer and simple sol-gel and combustion method at four different temperatures ranging from 300 to 700°C for 60 minutes. Data from X-ray and Fourier-transform infrared spectroscopy indicated that the ZnO nanoparticles fabricated at 600°C possessed better crystallinity, purity with least aggregation than other counterparts. This was followed by immersing the fabricated ZnO-nanoparticles (NPs) in the chitosan solution to synthesize facile Cs/ZnO nanocomposites (NCs) and develop cross-linked Chitosan/ZnO nanocomposites (NCs) using sodium tripolyphosphate (TPP). The successful chitosan coating on ZnO nanoparticles and synthesis of cross-linked Cs/ZnO-NCs were shown by ultraviolet-visible, X-ray, and Fourier-transform infrared spectroscopy. Cs/ZnO-NCs were produced for better stability in anticancer activities due to their biocompatibility and stability under harsh environments. Further, the potential anticancer activities of ZnO and Cs/ZnO-NCs were in vitro studied against various cancer cell lines of rhabdomyosarcoma (RD), pancreatic (AsPC-1), breast (MCF7), colon (Caco-2), lung (A-549), colon (HCT116) and embryonic normal kidney cells (293T). In in vitro anticancer assays, both ZnO and Cs/ZnO nanocomposites exhibited significant cytotoxicity on the tested cancer cells. The results indicated that Cs/ZnO-NCs coatings and cross-linked Cs/ZnO-NCs increased anticancer effect with the maximum killing effect of 85% and 100 % against Caco-2 and HCT116 cancer cells respectively. This discovery may provide a ray of hope for the easy and low-cost production of anticancer agents. These results also support the potential use of carrageenan-mediated ZnO-NPs coated with chitosan for prospective and low-cost anticancer efficacy. Therefore, the green synthesized CS/ZnO nanoparticles can be considered as a low-cost nanotherapeutic agent for cancer treatments.

ABSTRAK

Perkembangan komposit yang berasaskan logam-oksida boleh menjadi permulaan kepada rawatan kanser lanjutan. Selama bertahun-tahun, nanozarah zink oksida (ZnO-NPs) telah mendapat perhatian penyelidikan yang sewajarnya untuk potensi aplikasinya dalam pelbagai bidang termasuk dunia perubatan. Bahan kimia memudaratkan kesihatan manusia dan alam sekitar apabila digunakan dalam sintesis zarah nano yang berbeza. Kajian ini bertujuan untuk membuat facile zink oksida nanozarah menggunakan karagenan sebagai penstabil hijau dan kaedah sol-gel mudah dan pembakaran pada empat suhu berbeza antara 300 hingga 700°C selama 60 minit. Data daripada spektroskopi inframerah sinar-X dan *Fourier-transform* menunjukkan bahawa nanozarah ZnO yang difabrikasi pada suhu 600°C mempunyai kehabluran yang lebih baik, ketulenan dengan pengagregatan paling sedikit berbanding rakan sejawat lain. Ini diikuti dengan merendam ZnO-nanopartikel (NPs) yang direka dalam larutan kitosan untuk mensintesis nanokomposit (NCs) Cs/ZnO yang mudah dan membangunkan nanokomposit Chitosan/ZnO (NCs) berkait silang menggunakan natrium tripolifosfat (TPP). Salutan kitosan yang berjaya pada nanopartikel ZnO dan sintesis Cs/ZnO-NC berkait silang ditunjukkan oleh spektroskopi inframerah ultraungu-kelihatan, sinar-X dan *Fourier-transform*. Cs/ZnO-NCs dihasilkan untuk kestabilan yang lebih baik dalam aktiviti antikanser kerana biokompatibiliti dan kestabilannya di bawah persekitaran yang keras. Selanjutnya, potensi aktiviti antikanser ZnO dan Cs/ZnO-NCs telah dikaji secara in vitro terhadap pelbagai saluran sel kanser rhabdomyosarcoma (RD), pankreas (AsPC-1), payudara (MCF7), kolon (Caco-2), paru-paru (A-549), kolon (HCT116) dan sel buah pinggang normal embrio (293T). Ujian antikanser in vitro, kedua-dua nanokomposit ZnO dan Cs/ZnO menunjukkan sitotoksisiti yang ketara pada sel-sel kanser yang diuji. Dapatan menunjukkan bahawa salutan Cs/ZnO-NCs dan Cs/ZnO-NCs berkait silang meningkatkan kesan antikanser dengan kesan membunuh maksimum masing-masing sebanyak 85% dan 100 % terhadap sel kanser Caco-2 dan HCT116. Penemuan ini mungkin memberikan sinar harapan untuk pengeluaran agen antikanser yang mudah dan kos rendah. Dapatan ini juga menyokong potensi penggunaan ZnO-NPs pengantara karagenan yang disalut dengan kitosan untuk keberkesanan antikanser yang mempunyai prospektif dan kos yang rendah. Oleh itu, nanozarah CS/ZnO yang disintesis hijau boleh dianggap sebagai agen nanoterapi kos rendah untuk rawatan kanser.

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LIST OF ABBREVIATIONS

ZnO-NPs	-	Zinc Oxide Nanoparticles
Cs/ZnO	-	Chitosan/Zinc Oxide
NCs	-	Nanocomposites
RD	-	Rhabdomyosarcoma Cancer Cells
ASPC1	-	Pancreatic Cancer Regar Cancer Cells
MCF7	-	Breast Adenocarcinoma Cancer Cell
CACO-2	-	Colon Adenocarcinoma Cancer Cells
A549	-	Lung Carcinoma Cancer Cells
T293	-	Embryonic Normal Human Kidney Cells
HCT116	-	Colorectal Carcinoma Cancer Cells
FWHM	-	Full Width at Half Maximum
OD	-	Optical Density
FTIR	-	Fourier Transform Infrared (FT-IR) Spectroscopy
XRD	-	X-ray Diffraction
FESEM	-	Field Emission Scanning Microscopy
HRTEM	-	High Resolution Transmission Electron Microscopy
UV-vis	-	Ultra Violet-Visible Spectroscopy
EDX	-	Energy Dispersive X-ray
TGA	-	Thermogravimetric Analysis
DTA	-	Differential Thermal Analysis
FWHM	-	Full Width at Half Maximum
OD	-	Optical Density
nm	-	Nanometers

LIST OF SYMBOLS

λ	-	X-ray Wavelength
β	-	Line Broadening at Half the Maximum Intensity (FWHM)
θ	-	Bragg angle

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nanotechnology has attained great attention as an arising field of modern science and technology [1]. It is a branch of science concerned with the manipulation and production of nanoscale materials and electronics [2]. Nanomaterials are nanoparticles with nanoscale dimensions ranging from 1 to 100 nanometers [3, 4]. Because of their high surface area to volume ratio in comparison to bulk substances, these nanomaterials have unique physiochemical features such as increased thermal conductivity, catalytic reactivity, chemical stability, and non-linear optical performance [1, 5]. Nanoparticles aren't new to the environment; they're found in clays, minerals, and bacterial products. Engineered nanoparticles are made up of a range of nanoparticles in various shapes and sizes, which are separated from naturally occurring materials by a set of synthetic surface molecules [6].

Because of their exceptional optical, electrical, catalytic, and magnetic capabilities, metal and metal oxide nanoparticles are extremely important [7]. These nanoparticles are used in chemistry, physics, and materials research, among other applications. Their unique qualities enable them to be used in a wide range of medical, agricultural, environmental, and industrial domains. Traditional metal and metal oxide nanoparticle manufacturing processes use stabilising and reducing chemical agents that are detrimental to the environment, humans, and many wildlife. [7]. As a result, scientists are looking for alternate "green synthesis" approaches to eliminate or limit the use of chemicals in nanoparticle production.

One of the most important metal oxide nanoparticles is zinc oxide nanoparticles (ZnO-NPs), due to its unique physical and chemical properties, such as physical stability, chemical stability, high photosensitivity, non-toxicity, high thermal conductivity, wide band gap (3.37 eV) together with large excitation binding energy (60 meV) [4, 8]. It is a non-toxic and biocompatible material with a UV-filtering properties utilized as a UV blocker in sunscreen products [4]. Because of its UV filtering properties, it has been widely utilised in cosmetics such as sunscreen creams [5]. Bulk ZnO is also regarded to be a generally recognised as safe (GRAS) material by the US Food and Drug Administration (FDA), and ZnO-NPs larger than 100 nm are considered to be reasonably biocompatible, allowing for its usage in biomedical applications [9]. The ZnO-NPs are regularly used as delivery vehicles of various biomolecules such as drugs, proteins, and genes [10]. It's because ZnO-NPs are a pH-sensitive nanocarrier that's ideal for intracellular drug release and tumor-targeted drug delivery because they dissolve quickly at low pH [10]. Beside that it has a wide scope of biomedical applications where they could be employed for the therapy of various diseases such as cancer, diabetes, cardiovascular disease, microbial and fungal infection and ischemic [1]. Furthermore, an average individual need 2-3 g of zinc and 10-15 mg of zinc every day for optimal growth and physiology [11]. Apart from these characteristics, ZnO nanostructures have high catalytic efficiency and solid adsorption capacity, and are rapidly being used in the manufacture of sunscreens, fungicide, rubber processing, ceramics and wastewater treatment. Due to its low toxicity in vivo and vitro without stimulation, synthetic techniques that is both simple and environmentally friendly, with high catalytic efficiency, strong adsorption ability, and stable petrochemical properties, it has a wide range of applications in other fields such as agrochemicals, pharmaceuticals, perfumes, dyes, biology, and petroleum [12]. Interestingly, because of its durability in hostile environments, quick electron transfer kinetics, high biocompatibility, and extended life than organic-based disinfectants, the use of ZnO-NPs as an antibacterial agent has recently piqued interest in the development of microbiology and biomaterials [12]. Antimicrobial agents, medication delivery, bio imaging probes, and cancer treatment are among the next-generation biological uses that nano-crystalline ZnO is being studied for [13]. When ZnO-NPs combine with cell membrane lipids, they produce reactive oxygen species (ROS) and have increased toxicity against cancer cells in vitro [14]. Many studies have discovered that cancer cells are extremely vulnerable to ZnO-NPs toxicity, which occurs in a dose and time dependent way.

ZnO-NPs can be fabricated using chemical, physical and biological methodical approaches. Various methods for preparing ZnO-NPs have been reported, including solvothermal and hydrothermal synthesis [15], precipitation [16], polymerization method [17], laser ablation

[18], microwave irradiation [19], wet chemical method [20], photochemical method [21], sonochemical [22], and sol gel methods [23]. However, chemical and physical techniques have a number of drawbacks, including the use of high temperature and pressure, long reaction times, hazardous reagents, and the need for external additives such as a specific stabiliser, promoter, or base during the reaction, all of which limit the purity of the final product. Generally, nanoparticle synthesis is a complicated process with a wide range of variables that might influence the qualities of the final product when using various techniques of preparation. The ability to manipulate the ZnO-NPs' morphology and produce a restricted size distribution of the end product is critical. Chemical approaches result in the presence of harmful compounds adsorbed on the surface, which could have negative consequences in medical applications [24]. It is critical to synthesis ZnO-NPs using a simple, environmentally acceptable, low-cost approach that can manufacture nanomaterials with stable particle sizes. Because chemical and physical approaches are harmful and expensive, biological processes for green nanoparticle manufacturing involving microbes, enzymes, plants, and algae have been proposed as viable eco-friendly alternatives [25]. Natural polymers like starch, gelatin, and different proteins are all promising materials for nanomaterial production since they are bioabsorbable and biodegradable, with non-toxic degradation products [26].

For the manufacture of different metal oxide nanoparticles, natural biopolymers such as starch [27], carrageenan [28], cellulose [29], pullulan [30], chitosan [31] and gelatin [32] are employed. It is the recently discovered and promising candidates that have the potential to be manufactured as medication delivery vehicles [33]. Tissue adhesive and drug-carrying capabilities of natural polymers are unique [34]. As a green stabiliser, nanoparticles are produced from a variety of natural polymers.

Carrageenan, for example, is a biodegradable linear polysaccharide polymer derived from marine red seaweed. Carrageenan is widely utilised in the food business for its physical qualities such as thickening, gelling, and stabilising [35]. Chitosan (Cs) is a chitin-derived linear polysaccharide polymer. It is also well studied for possessing good mechanical properties, non-toxicity, abundant availability, biodegradability, antimicrobial activity and low cost [36, 37]. Moreover, Cs together with amine and hydroxyl functional groups makes it notable choice to utilize as a stabilizer and a cross-linker to connect diverse drugs to a metal oxide core [38]. In the intracellular environment, the chitosan amine group will promote solubility and provide hemocompatibility [39]. Furthermore, the surface of nanoparticles interacts with numerous cellular components which are exceptionally anionic in nature. The mucoadhesive property of Cs will allow the encapsulated component to interact with the cells for longer. The presence of Cs on the particle surface may also aid in the opening of tight intracellular junctions, thereby boosting cellular absorption and thus therapeutic efficiency [39]. Several biopolymers have been employed in medication delivery studies to increase therapeutic efficacy while reducing negative effects [34]. Many research also demonstrated a simple, economical, and environmentally friendly fabricationof ZnO-NPs employing the biopolymer *kappa carrageenan* as the stabilising, capping, and reducing agent, as well as Cs as the stabilising, capping, and reducing agent. [40].

In just one year, 18.1 million new cancer cases were displayed over the world [29]. Cancer is a terrible disease that arises as a result of a succession of molecular-level genetic events that disrupt the control over cell division, resulting in unregulated division and, finally, cancer [41]. Radiotherapies and chemotherapies are ineffective and aggressive, therefore cancer therapy remains a major issue for medicine [42]. These traditional anticancer medicines have side drawbacks like nausea, fatigue, sleeplessness, vomiting and delirium, which are all typical complaints among cancer patients [42]. Several investigations have been conducted on the anti-cancer properties of ZnO-NPs. ZnO-NPs cross-linked with biopolymer have shown to have a strong anticancer impact against human breast cancer cell (MCF-7 cell line) [14], AGS gastric cancer cells [43], Human Cervical cancer (HeLa) [44], human colon cancer HCT-116 [45], colorectal cancer (HCT116) [29], human colorectal adenocarcinoma cells (Caco-2 cell line) [46]. Up to date, there is no report the preparation of cross-linked biopolymer mixed with ZnO-NPs for cancer treatment activities.

Based on these considerations, the current research concentrated on the integration of nanoparticles with biopolymers. The goal of this study was to use a green synthesis approach to make biopolymer carrageenan-based ZnO-NPs. Thermal decomposition was utilised to successfully fabricate ZnO-NPs at varied temperatures. The syntheses of ZnO-NPs via green method at various calcination temperatures, as well as the fabrication of Chitosan/ZnO nanocomposite (Cs/ZnO-NCs) coatings and cross-linked Chitosan/ZnO nanocomposite (Cs/ZnO-NCs), are the main emphasis of this research.

Fourier transform infrared (FTIR) spectroscopy, X-ray diffraction pattern (XRD), UV-vis spectroscopy, High resolution transmission electron microscopy (HR-TEM), energy dispersive X-ray analysis (EDX), field emission-scanning electron microscopy (FESEM) and thermogravimetric analysis (TGA) were used to characterise the physiochemical properties of ZnO-NPs and nanocomposites. At five different concentrations, MTS in vitro cytotoxicity assays assessed the cytotoxicity of NPs and NCs against pancreatic cancer, human rhabdomyosarcoma RD, breast adenocarcinoma, colon adenocarcinoma, lung carcinoma, colorectal carcinoma and embryonic kidney (normal human cell) cells after 24 hours.

1.2 Problem Statement

Physical, chemical, and green synthesis approaches have all been applied in the production of nanoparticles. NPs have been synthesised using a variety of ways, the chemical and physical methods were found has a serious hazardous and high toxicity for living organisms then is the biggest problems that limit the involvement of nanoparticles in the biomedical industry. Indeed, the synthesis of this material plays a huge role for the development and improvement of our technology today.

Cancer is one of the lethal diseases which has low survival rate. Cancer treatment approaches like chemotherapy and radiotherapy are aggressive and ineffective, therefore, cancer treatment approaches remains a major issue in medicine world. For decades, anticancer medications such as 5-FU have been the preferred chemotherapy treatment. On the other hand, the negative side effects of administering 5-FU-based chemotherapy can result in stomatitis, diarrhoea, and gastrointestinal mucosal injury, among other things [47]. The extended chemotherapy time and nonspecific defensive mechanisms of 5-FU may cause damage in normal healthy cells. [48]. Chemotherapy along with the severe side effects of commonly used drugs has raised the urgency in the search for alternative cancer treatments that are generally safe. Furthermore, as compared to other nanoparticles, ZnO-NPs are well-known for their cytotoxicity against cancerous cells in vitro [49].

1.3 Research Objectives

The objective is to develop Chitosan/ZnO nanocomposite through green synthesized zinc oxide nanoparticles and to study in vitro cytotoxicity and anticancer effects for further applications.
Followings are the objectives proposed for this study:

(a) To synthesize biopolymer mediated ZnO-NPs and further fabrication of Cs/ZnO-NCs coatings and cross-linked Cs/ZnO-NCs via green method.

(b) To evaluate the physicochemical properties of ZnO-NPs, Cs/ZnO-NCs coatings and cross-linked Cs/ZnO-NCs.

(c) To determine the efficiency of cytotoxicity assay for ZnO-NPs, Cs/ZnO-NCs coatings and cross-linked Cs/ZnO-NCs.

1.4 Scope of the Study

To complete all the objectives in this project, the scopes must comply with all the listed objectives. Hence, below are some brief descriptions of the research scope for this study.

(1) Fabrications of ZnO-NPs were carried out using a green method using carrageenan as a stabilizing agent by sol-gel technique following thermal calcination in a furnace. Later, Cs/ZnO-NCs coatings and cross-linked Cs/ZnO-NCs were synthesized for further applications.

(2) Fabricated ZnO-NPs were characterized structurally, morphologically, and electrically using various techniques such as XRD, FTIR, UV-vis, TGA, FESEM, EDX, and TEM for

the stable formulations of nanoparticles. Successful green synthesis of Cs/ZnO-NCs was also proved using XRD, FTIR, TEM and EDX analyzing tools.

(3) Anticancer effects of ZnO-NPs, Cs/ZnO-NCs coating and cross-linked Cs/ZnO-NCs were evaluated using MTS against normal human cell and various cancer cells.

1.5 Significance of the Research

The unique features of ZnO-NPs made with biopolymer make them appealing for usage in medicinal and industrial applications, hence environmentally benign methods for their synthesis are required. This can be achieved by using Cs instead of typical chemical compounds to reduce zinc ions to ZnO-NPs during production. The production of cross-linked Cs/ZnO-NCs with reinforced features, with the goal of controlling the enteric release of ZnO-NPs, is the most important aspect of the research. The composite architectures were developed to keep acid-soluble chitosan in the internal phase of the complex to shield ZnO from the gastric acid environment [50]. Cross-linked chitosan's cross-linking density, crystallinity, and hydrophilicity can be used to modulate ZnO-NPs and expand their spectrum of possible uses in drug delivery systems [51].

Cancer is one of the world's major causes of death. It cannot be denied that cancer diagnoses are increasing in younger generations nowadays which may be due to the modern lifestyle. Many researchers are interested and working hard in developing a cure which can eliminate cancer cells utterly. Since ZnO-NPs are designed to be applied in human body, the biocompatibility and toxicity are also the major concerns of researchers. Thus, the outcome of this research will become the main interest to many anticancer researchers who are looking towards designing and fabricating new anticancer drug delivery agents. This research would also provide an understanding of how the ZnO-NPs can be applied in cytotoxicity with enhanced properties with selective cancer killing ability.

1.6 Outline of Thesis

Introduction, literature review, methods, results and discussion, and conclusion are the five key chapters of this thesis. As for the introduction, which is the first chapter, it consists of the background of this study which elaborates on the overall idea. Then, current problems related to this study are addressed in the problem statement followed by the objectives which are the main part of the introduction. The research scope and the significance of the study are stated in brief about the overall flow project in this study.

Next, the second chapter is the literature review. This part is about finding the research gap related to this project based on the previous studies. Apart from that, it also discussed in deep on the previous works of literature that are similar to the project to get the ideas and come up with a new solution that can be done in this project. For example, the metal and metal oxide nanoparticles, ZnO-NPs, synthesis methods of ZnO-NPs, green synthesis method, biomedical applications including cytotoxicity and anticancer treatment effects. The methodology is the third chapter in this study. This part is describing on the research flow and the methods used on how to achieve the objectives. Flow charts and the list of the chemical are present in this chapter.

Chapter four discusses both the synthesis of ZnO-NPs, Cs/ZnO-NPs coating and cross-linked Cs/ZnO-NCs with their characterizations followed by the efficiency of cytotoxicity of those NPs and NCs against various cancer cells. Lastly, chapter five presents the research conclusion of green synthesized ZnO-NPs, Cs/ZnO-NPs coating and cross-linked Cs/ZnO-NCs followed by the recommendation for future works in the synthesis.

REFERENCES

1. Barui, A.K., R. Kotcherlakota, and C.R. Patra, *Biomedical applications of zinc oxide nanoparticles*, in *Inorganic Frameworks as Smart Nanomedicines*. 2018. p. 239-278.
2. Randa Fawzi Elsupikhe, K.S., Mansor B Ahmad, Nor Azowa Ibrahim and Norhazlin Zainudin, *Green sonochemical synthesis of silver nanoparticles at varying concentrations of k-carrageenan.* Nanoscale Reserach Letters, 2015.
3. Abdelhakim, H.K., E.R. El-Sayed, and F.B. Rashidi, *Biosynthesis of zinc oxide nanoparticles with antimicrobial, anticancer, antioxidant and photocatalytic activities by the endophytic Alternaria tenuissima.* J Appl Microbiol, 2020. **128**(6): p. 1634-1646.
4. Sadhasivam, S., Shanmugam, M., Umamaheswaran, P. D., Venkattappan, A., & Shanmugam, A., *Zinc Oxide Nanoparticles: Green Synthesis and Biomedical Applications.* Journal of Cluster Science, 2020.
5. Agarwal, H., S. Venkat Kumar, and S. Rajeshkumar, *A review on green synthesis of zinc oxide nanoparticles – An eco-friendly approach.* Resource-Efficient Technologies, 2017. **3**(4): p. 406-413.
6. Rastogi, A., Zivcak, M., Sytar, O., Kalaji, H. M., He, X., Mbarki, S., & Brestic, M., *Impact of Metal and Metal Oxide Nanoparticles on Plant: A Critical Review.* Front Chem, 2017. **5**: p. 78.
7. Nguyen, N. H., Padil, V. V. T., Slaveykova, V. I., Černík, M., & Ševců, A., *Green Synthesis of Metal and Metal Oxide Nanoparticles and Their Effect on the Unicellular Alga Chlamydomonas reinhardtii.* Nanoscale Res Lett, 2018. **13**(1): p. 159.
8. Aminuzzaman, M., Ng, P. S., Goh, W. S., Ogawa, S., & Watanabe, A., *Value-adding to dragon fruit (Hylocereus polyrhizus) peel biowaste: green synthesis of ZnO nanoparticles and their characterization.* Inorganic and Nano-Metal Chemistry, 2019. **49**(11): p. 401-411.
9. Mishra, P. K., Mishra, H., Ekielski, A., Talegaonkar, S., & Vaidya, B., *Zinc oxide nanoparticles: a promising nanomaterial for biomedical applications.* Drug Discov Today, 2017. **22**(12): p. 1825-1834.

10. Wang, J., Lee, J. S., Kim, D., & Zhu, L., *Exploration of Zinc Oxide Nanoparticles as a Multitarget and Multifunctional Anticancer Nanomedicine.* ACS Appl Mater Interfaces, 2017. **9**(46): p. 39971-39984.

11. Krishna, P. G., Ananthaswamy, P. P., Yadavalli, T., Mutta, N. B., Sannaiah, A., & Shivanna, Y., *ZnO nanopellets have selective anticancer activity.* Materials Science and Engineering: C, 2016. **62**: p. 919-926.

12. Wu, D., Chen, Z., Cai, K., Zhuo, D., Chen, J., & Jiang, B., *Investigation into the antibacterial activity of monodisperse BSA-conjugated zinc oxide nanoparticles.* Current Applied Physics, 2014. **14**(11): p. 1470-1475.

13. A Rama Narsimha, R. and S. L, *Evaluation of In Vitro Cytotoxicity of Zinc Oxide (Zno) Nanoparticles Using Human Cell Lines.* Journal of Toxicology and Risk Assessment, 2018. **4**(1).

14. Rauf, M. A., Oves, M., Rehman, F. U., Khan, A. R., & Husain, N., *Bougainvillea flower extract mediated zinc oxide's nanomaterials for antimicrobial and anticancer activity.* Biomedicine & Pharmacotherapy, 2019. **116**.

15. Lepot, N., Van Bael, M. K., Van den Rul, H., D'haen, J., Peeters, R., Franco, D., & Mullens, J., *Influence of incorporation of ZnO nanoparticles and biaxial orientation on mechanical and oxygen barrier properties of polypropylene films for food packaging applications.* Journal of Applied Polymer Science, 2011. **120**(3): p. 1616-1623.

16. Herrera-Rivera, R., M.d.l.L. Olvera, and A. Maldonado, *Synthesis of ZnO Nanopowders by the Homogeneous Precipitation Method: Use of Taguchi's Method for Analyzing the Effect of Different Variables.* Journal of Nanomaterials, 2017. **2017**: p. 1-9.

17. Mansour, S., A. Farha, and M. Kotkata, *Synthesis and study of ZnO nanoparticles by polymer pyrolysis route using two different polymerization initiators.* International Journal of Applied Ceramic Technology, 2017. **14**(6): p. 1213-1221.

18. Lin, Z., Yue, J., Liang, L., Tang, B., Liu, B., Ren, L., ... & Jiang, L., *Rapid synthesis of metallic and alloy micro/nanoparticles by laser ablation towards water.* Applied Surface Science, 2020. **504**.

19. Faezah Farzaneh, Z.A., Fatemah Nouroozi, Sara Haghshenas, *Rapid Synthesis and Characterization of Zinc Oxide Nanoparticles with Albumen as Photodegradation of Congo Red Under Microwave Irradation.* 2017.

20. Mariappan Premanathan, K.K., Kadarkaraithangam Jeyasubramanian, Govindasamy Manivannnan, *Selective toxicity of ZnO nanoparticles toward Gram-positive bacteria and cancer cells by apoptosis through lipid perocidation.* Nanomedicine: Nanotechnology, Biology and Medicine, 2011: p. 184-192.
21. Randa Fawzi Elsupikhe, M.B.A., Kamyar Shameli, Nor Azowa Ibrahim, Norhazlin Zainuddin, *Photochemical reduction as a green method for the synthesis and size control of silver nanoparticles in k-carrageenan.* Nanoscale Research Letters, 2015.
22. Elsupikhe, R. F., Shameli, K., Ahmad, M. B., Ibrahim, N. A., & Zainudin, N., *Green sonochemical synthesis of silver nanoparticles at varying concentrations of kappa-carrageenan.* Nanoscale Res Lett, 2015. **10**(1): p. 916.
23. Majid Darroudi, Z.S., Reza Kazemi Oskuee, Hadi Kargar, Hasan Ali Hosseini, *Neuronal toxicity of biopolymer-template synthesized ZnO nanoparticles.* Nanomedicine Journal, 2013: p. 88-93.
24. Sangeetha Gunalan, R.S., Venckatesh Rajendran, *Green synthesized ZnO nanoparticles against bacterial and fungal pathogens.* Progress In Natural Science: Materials International, 2012. **6**: p. 693-700.
25. Susan Azizi, M.B.A., Farideh Namvar, Rosfarizan Mohamad, *Green biosynthesis and characterization of zinc oxide nanoparticles using brown marine macroalgae Sargassum muticum aqueous extract.* Materials Letters, 2014: p. 275-277.
26. Majid Darroudi, Z.S., Reza Kazemi Oskuee, Ali Khorsand Zak, Hadi Kargar, Mohamad Hasnul Naim Abd Hamid, *Green chemistry approach for the synthesis of ZnO nanopowders and their cytotoxic effects.* Ceramics International, 2014. **40**: p. 4827-4831.
27. Luo, Z., Dong, K., Guo, M., Lian, Z., Zhang, B., & Wei, W., *Preparation of Zinc Oxide Nanoparticles-Based Starch Paste and its Antifungal Performance as a Paper Adhesive.* Starch - Stärke, 2018. **70**(7-8).
28. Pandey, S., Do, J. Y., Kim, J., & Kang, M., *Fast and highly efficient catalytic degradation of dyes using kappa-carrageenan stabilized silver nanoparticles nanocatalyst.* Carbohydr Polym, 2020. **230**: p. 115597.
29. Yusefi, M., Shameli, K., Jahangirian, H., Teow, S. Y., Umakoshi, H., Saleh, B., ... & Webster, T. J., *The Potential Anticancer Activity of 5-Fluorouracil Loaded in Cellulose Fibers Isolated from Rice Straw.* Int J Nanomedicine, 2020. **15**: p. 5417-5432.

30. Isa, E. D. M., Shameli, K., Jusoh, N. W. C., & Hazan, R., *Rapid photodecolorization of methyl orange and rhodamine B using zinc oxide nanoparticles mediated by pullulan at different calcination conditions.* Journal of Nanostructure in Chemistry, 2020.
31. Priya, K., M. Vijayakumar, and B. Janani, *Chitosan-mediated synthesis of biogenic silver nanoparticles (AgNPs), nanoparticle characterisation and in vitro assessment of anticancer activity in human hepatocellular carcinoma HepG2 cells.* Int J Biol Macromol, 2020. **149**: p. 844-852.
32. Ye, H., J. Cheng, and K. Yu, *In situ reduction of silver nanoparticles by gelatin to obtain porous silver nanoparticle/chitosan composites with enhanced antimicrobial and wound-healing activity.* Int J Biol Macromol, 2019. **121**: p. 633-642.
33. Qureshi, D., Nayak, S. K., Maji, S., Kim, D., Banerjee, I., & Pal, K., *Carrageenan: A Wonder Polymer from Marine Algae for Potential Drug Delivery Applications.* Curr Pharm Des, 2019. **25**(11): p. 1172-1186.
34. Vijayakumar, S. and B. Vaseeharan, *Antibiofilm, anti cancer and ecotoxicity properties of collagen based ZnO nanoparticles.* Advanced Powder Technology, 2018. **29**(10): p. 2331-2345.
35. Abdelgawad, A. M., El-Naggar, M. E., Elsherbiny, D. A., Ali, S., Abdel-Aziz, M. S., & Abdel-Monem, Y. K., *Antibacterial carrageenan/cellulose nanocrystal system loaded with silver nanoparticles, prepared via solid-state technique.* Journal of Environmental Chemical Engineering, 2020. **8**(5).
36. Kumar, S., Mudai, A., Roy, B., Basumatary, I. B., Mukherjee, A., & Dutta, J., *Biodegradable Hybrid Nanocomposite of Chitosan/Gelatin and Green Synthesized Zinc Oxide Nanoparticles for Food Packaging.* Foods, 2020. **9**(9).
37. Li, L. H., Deng, J. C., Deng, H. R., Liu, Z. L., & Xin, L., *Synthesis and characterization of chitosan/ZnO nanoparticle composite membranes.* Carbohydr Res, 2010. **345**(8): p. 994-8.
38. Ghaffari, S. B., Sarrafzadeh, M. H., Salami, M., & Khorramizadeh, M. R., *A pH-sensitive delivery system based on N-succinyl chitosan-ZnO nanoparticles for improving antibacterial and anticancer activities of curcumin.* Int J Biol Macromol, 2020. **151**: p. 428-440.

39. Wu, H. and J. Zhang, *Chitosan-based zinc oxide nanoparticle for enhanced anticancer effect in cervical cancer: A physicochemical and biological perspective.* Saudi Pharm J, 2018. **26**(2): p. 205-210.

40. Vijayakumar, S., Saravanakumar, K., Malaikozhundan, B., Divya, M., Vaseeharan, B., Durán-Lara, E. F., & Wang, M. H., *Biopolymer K-carrageenan wrapped ZnO nanoparticles as drug delivery vehicles for anti MRSA therapy.* Int J Biol Macromol, 2020. **144**: p. 9-18.

41. Hameed, S., Iqbal, J., Ali, M., Khalil, A. T., Abbasi, B. A., Numan, M., & Shinwari, Z. K., *Green synthesis of zinc nanoparticles through plant extracts: establishing a novel era in cancer theranostics.* Materials Research Express, 2019. **6**(10).

42. Upadhyaya, L., Singh, J., Agarwal, V., Pandey, A. C., Verma, S. P., Das, P., & Tewari, R. P., *Efficient water soluble nanostructured ZnO grafted O-carboxymethyl chitosan/curcumin-nanocomposite for cancer therapy.* Process Biochemistry, 2015. **50**(4): p. 678-688.

43. Tang, Q., Xia, H., Liang, W., Huo, X., & Wei, X., *Synthesis and characterization of zinc oxide nanoparticles from Morus nigra and its anticancer activity of AGS gastric cancer cells.* J Photochem Photobiol B, 2020. **202**: p. 111698.

44. Dulta, K., Ağçeli, G. K., Chauhan, P., Jasrotia, R., & Chauhan, P. K., *A Novel Approach of Synthesis Zinc Oxide Nanoparticles by Bergenia ciliata Rhizome Extract: Antibacterial and Anticancer Potential.* Journal of Inorganic and Organometallic Polymers and Materials, 2020.

45. Majeed, S., Danish, M., Ismail, M. H. B., Ansari, M. T., & Ibrahim, M. N. M., *Anticancer and apoptotic activity of biologically synthesized zinc oxide nanoparticles against human colon cancer HCT-116 cell line- in vitro study.* Sustainable Chemistry and Pharmacy, 2019. **14**.

46. Rajan, M., Anthuvan, A. J., Muniyandi, K., Kalagatur, N. K., Shanmugam, S., Sathyanarayanan, S., ... & Narain, N., *Comparative Study of Biological (Phoenix loureiroi Fruit) and Chemical Synthesis of Chitosan-Encapsulated Zinc Oxide Nanoparticles and their Biological Properties.* Arabian Journal for Science and Engineering, 2019. **45**(1): p. 15-28.

47. Yusefi, M., Shameli, K., Hedayatnasab, Z., Teow, S. Y., Ismail, U. N., Azlan, C. A., & Ali, R. R., *Green synthesis of Fe3O4 nanoparticles for hyperthermia, magnetic resonance imaging and 5-fluorouracil carrier in potential colorectal cancer treatment.* Research on Chemical Intermediates, 2021.
48. Yusefi, M., Shameli, K., Jahangirian, H., Teow, S. Y., Umakoshi, H., Saleh, B., ... & Webster, T. J., *The Potential Anticancer Activity of 5-Fluorouracil Loaded in Cellulose Fibers Isolated from Rice Straw.* International Journal of Nanomedicine, 2020. **15**: p. 5417.
49. Bisht, G. and S. Rayamajhi, *ZnO nanoparticles: a promising anticancer agent.* Nanobiomedicine, 2016. **3**(Godište 2016): p. 3-9.
50. Barreto, M. S., Andrade, C. T., da Silva, L. C. R., Cabral, L. M., Paschoalin, V. M. F., & Del Aguila, E. M., *In vitro physiological and antibacterial characterization of ZnO nanoparticle composites in simulated porcine gastric and enteric fluids.* BMC Vet Res, 2017. **13**(1): p. 181.
51. Bhumkar, D.R. and V.B. Pokharkar, *Studies on effect of pH on cross-linking of chitosan with sodium tripolyphosphate: a technical note.* AAPS PharmSciTech, 2006. **7**(2): p. E50.
52. Kolahalam, L. A., Viswanath, I. K., Diwakar, B. S., Govindh, B., Reddy, V., & Murthy, Y. L. N., *Review on nanomaterials: Synthesis and applications.* Materials Today: Proceedings, 2019. **18**: p. 2182-2190.
53. Khan, I., K. Saeed, and I. Khan, *Nanoparticles: Properties, applications and toxicities.* Arabian Journal of Chemistry, 2019. **12**(7): p. 908-931.
54. Jiang, J., J. Pi, and J. Cai, *The Advancing of Zinc Oxide Nanoparticles for Biomedical Applications.* Bioinorganic Chemistry and Applications, 2018. **2018**: p. 1-18.
55. Ahmed, S., Ahmad, M., Swami, B. L., & Ikram, S., *A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise.* Journal of Advanced Research, 2016. **7**(1): p. 17-28.
56. Teow, Y., Asharani, P. V., Hande, M. P., & Valiyaveettil, S., *Health impact and safety of engineered nanomaterials.* Chem Commun (Camb), 2011. **47**(25): p. 7025-38.
57. Shah, M., Badwaik, V., Kherde, Y., Waghwani, H. K., Modi, T., Aguilar, Z. P., ... & Dakshinamurthy, R., *Gold nanoparticles: various methods of synthesis and antibacterial applications.* Frontiers in Bioscience, 2014. **19**: p. 1320-1344.

58. Rawat, R.S., *Dense Plasma Focus - From Alternative Fusion Source to Versatile High Energy Density Plasma Source for Plasma Nanotechnology.* Journal of Physics: Conference Series, 2015. **591**.

59. Liu, S., Tian, J., Wang, L., Li, H., Zhang, Y., & Sun, X., *Stable Aqueous Dispersion of Graphene Nanosheets: Noncovalent Functionalization by a Polymeric Reducing Agent and Their Subsequent Decoration with Ag Nanoparticles for Enzymeless Hydrogen Peroxide Detection.* Macromolecules, 2010. **43**(23): p. 10078-10083.

60. Tan, Y., Wang, Y., Jiang, L., & Zhu, D., *Thiosalicylic acid-functionalized silver nanoparticles synthesized in one-phase system.* J Colloid Interface Sci, 2002. **249**(2): p. 336-45.

61. Liu, Y.-C. and L.-H. Lin, *New pathway for the synthesis of ultrafine silver nanoparticles from bulk silver substrates in aqueous solutions by sonoelectrochemical methods.* Electrochemistry Communications, 2004. **6**(11): p. 1163-1168.

62. Mallick, K., M.J. Witcomb, and M.S. Scurrell, *Self-assembly of silver nanoparticles in a polymer solvent: formation of a nanochain through nanoscale soldering.* Materials Chemistry and Physics, 2005. **90**(2-3): p. 221-224.

63. Smetana, A.B., K.J. Klabunde, and C.M. Sorensen, *Synthesis of spherical silver nanoparticles by digestive ripening, stabilization with various agents, and their 3-D and 2-D superlattice formation.* J Colloid Interface Sci, 2005. **284**(2): p. 521-6.

64. Frattini, A., Pellegri, N., Nicastro, D., & De Sanctis, O., *Effect of amine groups in the synthesis of Ag nanoparticles using aminosilanes.* Materials Chemistry and Physics, 2005. **94**(1): p. 148-152.

65. Thakkar, K.N., S.S. Mhatre, and R.Y. Parikh, *Biological synthesis of metallic nanoparticles.* Nanomedicine: nanotechnology, biology and medicine, 2010. **6**(2): p. 257-262.

66. Bandeira, M., Giovanela, M., Roesch-Ely, M., Devine, D. M., & da Silva Crespo, J., *Green synthesis of zinc oxide nanoparticles: A review of the synthesis methodology and mechanism of formation.* Sustainable Chemistry and Pharmacy, 2020. **15**.

67. Yusefi, M., Shameli, K., Yee, O. S., Teow, S. Y., Hedayatnasab, Z., Jahangirian, H., ... & Kuča, K., *Green synthesis of Fe3O4 nanoparticles stabilized by a Garcinia mangostana*

fruit peel extract for hyperthermia and anticancer activities. International Journal of Nanomedicine, 2021. **16**: p. 2515.

68. Lee, K. X., Shameli, K., Mohamad, S. E., Yew, Y. P., Mohamed Isa, E. D., Yap, H. Y., ... & Teow, S. Y., *Bio-Mediated Synthesis and Characterisation of Silver Nanocarrier, and Its Potent Anticancer Action.* Nanomaterials, 2019. **9**(10): p. 1423.

69. Wan Mat Khalir, W. K. A., Shameli, K., Jazayeri, S. D., Othman, N. A., Che Jusoh, N. W., & Mohd Hassan, N., *In-Situ Biofabrication of Silver Nanoparticles in Ceiba pentandra Natural Fiber Using Entada spiralis Extract with Their Antibacterial and Catalytic Dye Reduction Properties.* Nanomaterials, 2020. **10**(6): p. 1104.

70. Rolim, W. R., Pelegrino, M. T., de Araújo Lima, B., Ferraz, L. S., Costa, F. N., Bernardes, J. S., ... & Seabra, A. B., *Green tea extract mediated biogenic synthesis of silver nanoparticles: Characterization, cytotoxicity evaluation and antibacterial activity.* Applied Surface Science, 2019. **463**: p. 66-74.

71. Behravan, M., Panahi, A. H., Naghizadeh, A., Ziaee, M., Mahdavi, R., & Mirzapour, A., *Facile green synthesis of silver nanoparticles using Berberis vulgaris leaf and root aqueous extract and its antibacterial activity.* Int J Biol Macromol, 2019. **124**: p. 148-154.

72. Ismail, N. A., Shameli, K., Jusoh, N. C., & Ali, R. R., *Effect of size and shape dependent of synthesized copper nanoparticle using natural honey.* IOP Conference Series: Materials Science and Engineering, 2020. **808**.

73. Sharma, B.K., D.V. Shah, and D.R. Roy, *Green synthesis of CuO nanoparticles using Azadirachta indica and its antibacterial activity for medicinal applications.* Materials research express, 2018. **5**(9): p. 095033.

74. Shi, L. B., Tang, P. F., Zhang, W., Zhao, Y. P., Zhang, L. C., & Zhang, H., *Green synthesis of CuO nanoparticles using Cassia auriculata leaf extract and in vitro evaluation of their biocompatibility with rheumatoid arthritis macrophages (RAW 264.7).* Tropical Journal of Pharmaceutical Research, 2017. **16**(1): p. 185-192.

75. Santhoshkumar, J., S.V. Kumar, and S. Rajeshkumar, *Synthesis of zinc oxide nanoparticles using plant leaf extract against urinary tract infection pathogen.* Resource-Efficient Technologies, 2017. **3**(4): p. 459-465.

76. Aljabali, A. A., Akkam, Y., Al Zoubi, M. S., Al-Batayneh, K. M., Al-Trad, B., Abo Alrob, O., ... & Evans, D. J., *Synthesis of Gold Nanoparticles Using Leaf Extract of Ziziphus zizyphus and their Antimicrobial Activity.* Nanomaterials, 2018. **8**(3): p. 174.

77. Umamaheswari, C., A. Lakshmanan, and N.S. Nagarajan, *Green synthesis, characterization and catalytic degradation studies of gold nanoparticles against congo red and methyl orange.* J Photochem Photobiol B, 2018. **178**: p. 33-39.

78. Subhapriya, S. and P. Gomathipriya, *Green synthesis of titanium dioxide (TiO2) nanoparticles by Trigonella foenum-graecum extract and its antimicrobial properties.* Microb Pathog, 2018. **116**: p. 215-220.

79. Goutam, S. P., Saxena, G., Singh, V., Yadav, A. K., Bharagava, R. N., & Thapa, K. B., *Green synthesis of TiO2 nanoparticles using leaf extract of Jatropha curcas L. for photocatalytic degradation of tannery wastewater.* Chemical Engineering Journal, 2018. **336**: p. 386-396.

80. Amanulla, A.M. and R. Sundaram, *Green synthesis of TiO2 nanoparticles using orange peel extract for antibacterial, cytotoxicity and humidity sensor applications.* Materials Today: Proceedings, 2019. **8**: p. 323-331.

81. Suriyaraj, S. P., Ramadoss, G., Chandraraj, K., & Selvakumar, R., *One pot facile green synthesis of crystalline bio-ZrO2 nanoparticles using Acinetobacter sp. KCSI1 under room temperature.* Materials Science and Engineering: C, 2019. **105**: p. 110021.

82. Moradnia, F., Fardood, S. T., Ramazani, A., & Gupta, V. K., *Green synthesis of recyclable MgFeCrO4 spinel nanoparticles for rapid photodegradation of direct black 122 dye.* Journal of Photochemistry and Photobiology A: Chemistry, 2020. **392**.

83. Alijani, H. Q., Pourseyedi, S., Mahani, M. T., & Khatami, M., *Green synthesis of zinc sulfide (ZnS) nanoparticles using Stevia rebaudiana Bertoni and evaluation of its cytotoxic properties.* Journal of Molecular Structure, 2019. **1175**: p. 214-218.

84. Diko, C. S., Qu, Y., Henglin, Z., Li, Z., Nahyoon, N. A., & Fan, S., *Biosynthesis and characterization of lead selenide semiconductor nanoparticles (PbSe NPs) and its antioxidant and photocatalytic activity.* Arabian Journal of Chemistry, 2020. **13**(11): p. 8411-8423.

85. Bera, S.R. and S. Saha, *Biosynthesis and characterization of Thevetia peruviana leaf extract capped CdTe nanoparticles in photoconductive and photovoltaic applications.* Materials Today: Proceedings, 2018. **5**(2): p. 3476-3485.
86. Khodadadi, B., M. Bordbar, and M. Nasrollahzadeh, *Green synthesis of Pd nanoparticles at Apricot kernel shell substrate using Salvia hydrangea extract: catalytic activity for reduction of organic dyes.* Journal of colloid and interface science, 2017. **490**: p. 1-10.
87. Kumar, P.V., S.M.J. Kala, and K. Prakash, *Green synthesis derived Pt-nanoparticles using Xanthium strumarium leaf extract and their biological studies.* Journal of Environmental Chemical Engineering, 2019. **7**(3): p. 103146.
88. maheswari, U.A., L. Prabu S, and P. chikody A, *Biosynthesis of zinc oxide nanoparticle: a review on greener approach.* MOJ Bioequivalence & Bioavailability, 2018. **5**(3).
89. Akintelu, S.A. and A.S. Folorunso, *A Review on Green Synthesis of Zinc Oxide Nanoparticles Using Plant Extracts and Its Biomedical Applications.* BioNanoScience, 2020. **10**(4): p. 848-863.
90. Karakeçili, A., Korpayev, S., Dumanoğlu, H., & Alizadeh, S., *Synthesis of indole-3-acetic acid and indole-3-butyric acid loaded zinc oxide nanoparticles: Effects on rhizogenesis.* J Biotechnol, 2019. **303**: p. 8-15.
91. Cruz, D. M., Mostafavi, E., Vernet-Crua, A., Barabadi, H., Shah, V., Cholula-Díaz, J. L., ... & Webster, T. J., *Green nanotechnology-based zinc oxide (ZnO) nanomaterials for biomedical applications: a review.* Journal of Physics: Materials, 2020. **3**(3).
92. Mehr, E. S., Sorbiun, M., Ramazani, A., & Fardood, S. T., *Plant-mediated synthesis of zinc oxide and copper oxide nanoparticles by using ferulago angulata (schlecht) boiss extract and comparison of their photocatalytic degradation of Rhodamine B (RhB) under visible light irradiation.* Journal of Materials Science: Materials in Electronics, 2017. **29**(2): p. 1333-1340.
93. Khalil, A. T., Ovais, M., Ullah, I., Ali, M., Shinwari, Z. K., Khamlich, S., & Maaza, M., *Sageretia thea (Osbeck.) mediated synthesis of zinc oxide nanoparticles and its biological applications.* Nanomedicine, 2017. **12**(15): p. 1767-1789.
94. Vijayakumar, S., Vinoj, G., Malaikozhundan, B., Shanthi, S., & Vaseeharan, B., *Plectranthus amboinicus leaf extract mediated synthesis of zinc oxide nanoparticles and*

its control of methicillin resistant Staphylococcus aureus biofilm and blood sucking mosquito larvae. Spectrochim Acta A Mol Biomol Spectrosc, 2015. **137**: p. 886-91.

95. Anbuvannan, M., Ramesh, M., Viruthagiri, G., Shanmugam, N., & Kannadasan, N., *Anisochilus carnosus leaf extract mediated synthesis of zinc oxide nanoparticles for antibacterial and photocatalytic activities.* Materials Science in Semiconductor Processing, 2015. **39**: p. 621-628.

96. Taranath, T.C. and B.N. Patil, *Limonia acidissima L. leaf mediated synthesis of zinc oxide nanoparticles: A potent tool against Mycobacterium tuberculosis.* Int J Mycobacteriol, 2016. **5**(2): p. 197-204.

97. Rafique, M., Tahir, R., Gillani, S. S. A., Tahir, M. B., Shakil, M., Iqbal, T., & Abdellahi, M. O., *Plant-mediated green synthesis of zinc oxide nanoparticles from Syzygium Cumini for seed germination and wastewater purification.* International Journal of Environmental Analytical Chemistry, 2020: p. 1-16.

98. Sukri, S. N. A. M., Shameli, K., Wong, M. M. T., Teow, S. Y., Chew, J., & Ismail, N. A., *Cytotoxicity and antibacterial activities of plant-mediated synthesized zinc oxide (ZnO) nanoparticles using Punica granatum (pomegranate) fruit peels extract.* Journal of Molecular Structure, 2019. **1189**: p. 57-65.

99. Sukri, S.N.A.M., E.D.M. Isa, and K. Shameli, *Photocatalytic Degradation of Malachite Green Dye by Plant-mediated Biosynthesized Zinc Oxide Nanoparticles.* IOP Conference Series: Materials Science and Engineering, 2020. **808**.

100. Alrajhi, A. H., Ahmed, N. M., Al Shafouri, M., & Almessiere, M. A., *Green synthesis of zinc oxide nanoparticles using salvia officials extract.* Materials Science in Semiconductor Processing, 2021. **125**.

101. Dulta, K., Ağçeli, G. K., Chauhan, P., Jasrotia, R., & Chauhan, P. K., *Ecofriendly Synthesis of Zinc Oxide Nanoparticles by Carica papaya Leaf Extract and Their Applications.* Journal of Cluster Science, 2021.

102. El-Belely, E. F., Farag, M., Said, H. A., Amin, A. S., Azab, E., Gobouri, A. A., & Fouda, A., *Green Synthesis of Zinc Oxide Nanoparticles (ZnO-NPs) Using Arthrospira platensis (Class: Cyanophyceae) and Evaluation of their Biomedical Activities.* Nanomaterials (Basel), 2021. **11**(1).

103. Vijayakumar, S., Arulmozhi, P., Kumar, N., Sakthivel, B., Kumar, S. P., & Praseetha, P. K., *Acalypha fruticosa L. leaf extract mediated synthesis of ZnO nanoparticles: Characterization and antimicrobial activities.* Materials Today: Proceedings, 2020. **23**: p. 73-80.

104. Król, A., Railean-Plugaru, V., Pomastowski, P., & Buszewski, B., *Phytochemical investigation of Medicago sativa L. extract and its potential as a safe source for the synthesis of ZnO nanoparticles: The proposed mechanism of formation and antimicrobial activity.* Phytochemistry Letters, 2019. **31**: p. 170-180.

105. Irshad, S., Salamat, A., Anjum, A. A., Sana, S., Saleem, R. S., Naheed, A., & Iqbal, A., *Green tea leaves mediated ZnO nanoparticles and its antimicrobial activity.* Cogent Chemistry, 2018. **4**(1): p. 1469207.

106. Raghavendra, M., K. Yatish, and H. Lalithamba, *Plant-mediated green synthesis of ZnO nanoparticles using Garcinia gummi-gutta seed extract: Photoluminescence, screening of their catalytic activity in antioxidant, formylation and biodiesel production.* The European Physical Journal Plus, 2017. **132**(8): p. 1-12.

107. Duraimurugan, J., Kumar, G. S., Maadeswaran, P., Shanavas, S., Anbarasan, P. M., & Vasudevan, V., *Structural, optical and photocatlytic properties of zinc oxide nanoparticles obtained by simple plant extract mediated synthesis.* Journal of Materials Science: Materials in Electronics, 2019. **30**(2): p. 1927-1935.

108. Mari, A., R. Mookkaiah, and M. Elayaperumal, *Emblica officinalis leaf extract mediated synthesis of zinc oxide nanoparticles for antibacterial and photocatalytic activities.* Asian Journal of Green Chemistry, 2019. **3**(4): p. 418-431.

109. Abdelkhalek, A. and A.A. Al-Askar, *Green Synthesized ZnO Nanoparticles Mediated by Mentha Spicata Extract Induce Plant Systemic Resistance against Tobacco Mosaic Virus.* Applied Sciences, 2020. **10**(15): p. 5054.

110. Saraswathi, V. S., Tatsugi, J., Shin, P. K., & Santhakumar, K., *Facile biosynthesis, characterization, and solar assisted photocatalytic effect of ZnO nanoparticles mediated by leaves of L. speciosa.* Journal of Photochemistry and Photobiology B: Biology, 2017. **167**: p. 89-98.

111. Sharmila, G., M. Thirumarimurugan, and C. Muthukumaran, *Green synthesis of ZnO nanoparticles using Tecoma castanifolia leaf extract: Characterization and evaluation of*

its antioxidant, bactericidal and anticancer activities. Microchemical Journal, 2019. **145**: p. 578-587.

112. Akhter, S. M. H., Mahmood, Z., Ahmad, S., & Mohammad, F., *Plant-mediated green synthesis of zinc oxide nanoparticles using Swertia chirayita leaf extract, characterization and its antibacterial efficacy against some common pathogenic bacteria.* BioNanoScience, 2018. **8**(3): p. 811-817.

113. Hafeez, M., Arshad, R., Hameed, M. U., Akram, B., Ahmed, M. N., Kazmi, S. A., ... & Ali, S., *Populus ciliata leaves extract mediated synthesis of zinc oxide nanoparticles and investigation of their anti-bacterial activities.* Materials Research Express, 2019. **6**(7): p. 075064.

114. Darroudi, M., Sabouri, Z., Oskuee, R. K., Zak, A. K., Kargar, H., & Abd Hamid, M. H. N., *Green chemistry approach for the synthesis of ZnO nanopowders and their cytotoxic effects.* Ceramics International, 2014. **40**(3): p. 4827-4831.

115. El-saied, H.A.-a. and A.M. Ibrahim, *Effective Fabrication and Characterization of Eco-friendly Nano Chitosan Capped Zinc Oxide Nanoparticles for Effective Marine Fouling Inhibition.* Journal of Environmental Chemical Engineering, 2020. **8**(4).

116. Isa, E. M., Jusoh, N. C., Hazan, R., & Shameli, K., *Pullulan mediated zinc oxide microparticles: Effect of synthesis temperature.* IOP Conference Series: Materials Science and Engineering, 2020. **808**.

117. Shankar, S., S. Kasapis, and J.W. Rhim, *Alginate-based nanocomposite films reinforced with halloysite nanotubes functionalized by alkali treatment and zinc oxide nanoparticles.* Int J Biol Macromol, 2018. **118**(Pt B): p. 1824-1832.

118. L.V. Abad, H.K., S. Saiki, N. Nagasawa, M. Tamada, H. Fu, Y. Muroya, M. Lin, Y. Katsumura, L.S. Relleve, C. T. Aranilla, A.M. Delarosa, *Radiolysis studies of aqueous k-carrageenan.* Nuclear Instruments and Methods in Physics Research B, 2010. **268**: p. 1607-1612.

119. Noor, H.M., *Potential of carrageenan in foods and medical application.* Global Health Management Journal, 2018.

120. Vijayakumar, S., Saravanakumar, K., Malaikozhundan, B., Divya, M., Vaseeharan, B., Durán-Lara, E. F., & Wang, M. H., *Biopolymer K-carrageenan wrapped ZnO*

nanoparticles as drug delivery vehicles for anti MRSA therapy. International journal of biological macromolecules, 2020. **144**: p. 9-18.

121. Carp, O., Jurca, B., Ene, R., Somacescu, S., & Ianculescu, A., *Biopolymer starch mediated synthetic route of multi-spheres and donut ZnO structures.* Carbohydrate polymers, 2015. **115**: p. 285-293.

122. Isa, E. D. M., Shameli, K., Jusoh, N. W. C., & Hazan, R., *Rapid photodecolorization of methyl orange and rhodamine B using zinc oxide nanoparticles mediated by pullulan at different calcination conditions.* Journal of Nanostructure in Chemistry, 2021. **11**(1): p. 187-202.

123. Magesh, G., Bhoopathi, G., Nithya, N., Arun, A. P., & Kumar, E. R., *Structural, morphological, optical and biological properties of pure ZnO and agar/zinc oxide nanocomposites.* International journal of biological macromolecules, 2018. **117**: p. 959-966.

124. Rajalakshmi, T.U. and G. Alagumuthu, *Facile Synthesis of ZnO Nanocomposite By An Alginate Mediated Process And A Case Study For Photocatalytic degradation of MB Dye.*

125. Abinaya, M., Vaseeharan, B., Divya, M., Sharmili, A., Govindarajan, M., Alharbi, N. S., ... & Benelli, G., *Bacterial exopolysaccharide (EPS)-coated ZnO nanoparticles showed high antibiofilm activity and larvicidal toxicity against malaria and Zika virus vectors.* Journal of Trace Elements in Medicine and Biology, 2018. **45**: p. 93-103.

126. Bharathi, D., Ranjithkumar, R., Chandarshekar, B., & Bhuvaneshwari, V., *Preparation of chitosan coated zinc oxide nanocomposite for enhanced antibacterial and photocatalytic activity: As a bionanocomposite.* International journal of biological macromolecules, 2019. **129**: p. 989-996.

127. Ahmad Yusof, N.A., N. Mat Zain, and N. Pauzi, *Synthesis of Chitosan/Zinc Oxide Nanoparticles Stabilized by Chitosan via Microwave Heating.* 2019, 2019: p. 9.

128. Yusof, N.A.A., N.M. Zain, and N. Pauzi, *Synthesis of ZnO nanoparticles with chitosan as stabilizing agent and their antibacterial properties against Gram-positive and Gram-negative bacteria.* International journal of biological macromolecules, 2019. **124**: p. 1132-1136.

129. Singh, V., Dwivedi, L. M., Baranwal, K., Asthana, S., & Sundaram, S., *Oxidized guar gum–ZnO hybrid nanostructures: synthesis, characterization and antibacterial activity.* Applied Nanoscience, 2018. **8**(5): p. 1149-1160.

130. Liu, J., X. Wu, and M. Wang, *Biosynthesis of Zinc Oxide Nanoparticles Using Biological Polysaccharides for Application in Ceramics.* Journal of Electronic Materials, 2019. **48**(12): p. 8024-8030.

131. Shankar, S., Teng, X., Li, G., & Rhim, J. W., *Preparation, characterization, and antimicrobial activity of gelatin/ZnO nanocomposite films.* Food Hydrocolloids, 2015. **45**: p. 264-271.

132. Hossain, S. and M. Hoque, *Polymer nanocomposite materials in energy storage: Properties and applications*, in *Polymer-based Nanocomposites for Energy and Environmental Applications*. 2018, Elsevier. p. 239-282.

133. Yu, J., Wang, D., Geetha, N., Khawar, K. M., Jogaiah, S., & Mujtaba, M., *Current trends and challenges in the synthesis and applications of chitosan-based nanocomposites for plants: A review.* Carbohydrate Polymers, 2021: p. 117904.

134. Petronella, F., Truppi, A., Ingrosso, C., Placido, T., Striccoli, M., Curri, M. L., ... & Comparelli, R., *Nanocomposite materials for photocatalytic degradation of pollutants.* Catalysis Today, 2017. **281**: p. 85-100.

135. Mallakpour, S. and M. Darvishzadeh, *Nanocomposite materials based on poly (vinyl chloride) and bovine serum albumin modified ZnO through ultrasonic irradiation as a green technique: Optical, thermal, mechanical and morphological properties.* Ultrasonics sonochemistry, 2018. **41**: p. 85-99.

136. Csaba, N., Köping-Höggård, M., Fernandez-Megia, E., Novoa-Carballal, R., Riguera, R., & Alonso, M. J., *Ionically crosslinked chitosan nanoparticles as gene delivery systems: effect of PEGylation degree on in vitro and in vivo gene transfer.* Journal of biomedical nanotechnology, 2009. **5**(2): p. 162-171.

137. Liu, H. and C. Gao, *Preparation and properties of ionically cross-linked chitosan nanoparticles.* Polymers for Advanced Technologies, 2009. **20**(7): p. 613-619.

138. Soares, K. S. R., Oliveira, A. R., Daniele-Silva, A., Glaucia-Silva, F., Caroni, A. L. P., Fernandes-Pedrosa, M. F., & da Silva-Júnior, A. A., *Self-assembled scorpion venom*

proteins cross-linked chitosan nanoparticles for use in the immunotherapy. Journal of Molecular Liquids, 2017. **241**: p. 540-548.

139. Pan, C., Qian, J., Zhao, C., Yang, H., Zhao, X., & Guo, H., *Study on the relationship between crosslinking degree and properties of TPP crosslinked chitosan nanoparticles.* Carbohydrate Polymers, 2020. **241**: p. 116349.

140. Taghizadeh, M. T., Ashassi-Sorkhabi, H., Afkari, R., & Kazempour, A., *Cross-linked chitosan in nano and bead scales as drug carriers for betamethasone and tetracycline.* International journal of biological macromolecules, 2019. **131**: p. 581-588.

141. Islam, N., Wang, H., Maqbool, F., & Ferro, V., *In Vitro Enzymatic Digestibility of Glutaraldehyde-Crosslinked Chitosan Nanoparticles in Lysozyme Solution and Their Applicability in Pulmonary Drug Delivery.* Molecules, 2019. **24**(7): p. 1271.

142. Sharma, K., Somavarapu, S., Colombani, A., Govind, N., & Taylor, K. M., *Nebulised siRNA encapsulated crosslinked chitosan nanoparticles for pulmonary delivery.* International journal of pharmaceutics, 2013. **455**(1-2): p. 241-247.

143. Ribeiro, E. F., de Barros-Alexandrino, T. T., Assis, O. B. G., Junior, A. C., Quiles, A., Hernando, I., & Nicoletti, V. R., *Chitosan and crosslinked chitosan nanoparticles: Synthesis, characterization and their role as Pickering emulsifiers.* Carbohydrate Polymers, 2020. **250**: p. 116878.

144. Ray, S., Sinha, P., Laha, B., Maiti, S., Bhattacharyya, U. K., & Nayak, A. K., *Polysorbate 80 coated crosslinked chitosan nanoparticles of ropinirole hydrochloride for brain targeting.* Journal of Drug Delivery Science and Technology, 2018. **48**: p. 21-29.

145. Soares, K. S. R., Fonseca, J. L. C., Bitencourt, M. A. O., Santos, K. S., Silva-Júnior, A. A., & Fernandes-Pedrosa, M. F., *Serum production against Tityus serrulatus scorpion venom using cross-linked chitosan nanoparticles as immunoadjuvant.* Toxicon, 2012. **60**(8): p. 1349-1354.

146. Vila-Sanjurjo, C., Hembach, L., Netzer, J., Remuñán-López, C., Vila-Sanjurjo, A., & Goycoolea, F. M., *Covalently and ionically, dually crosslinked chitosan nanoparticles block quorum sensing and affect bacterial cell growth on a cell-density dependent manner.* Journal of Colloid and Interface Science, 2020. **578**: p. 171-183.

147. Kahdestani, S.A., M.H. Shahriari, and M. Abdouss, *Synthesis and characterization of chitosan nanoparticles containing teicoplanin using sol–gel.* Polymer Bulletin, 2021. **78**(2): p. 1133-1148.

148. Mahmood, M. A., Madni, A., Rehman, M., Rahim, M. A., & Jabar, A., *Ionically cross-linked chitosan nanoparticles for sustained delivery of docetaxel: fabrication, post-formulation and acute oral toxicity evaluation.* International journal of nanomedicine, 2019. **14**: p. 10035.

149. Xiong, J., Shen, L., Jiang, Q., & Kishen, A., *Effect of Crosslinked Chitosan Nanoparticles on the Bonding Quality of Fiber Posts in Root Canals.* Journal of Adhesive Dentistry, 2020. **22**(3).

150. Torres-Rego, M., Glaucia-Silva, F., Soares, K. S. R., de Souza, L. B. F. C., Damasceno, I. Z., dos Santos-Silva, E., ... & de Freitas Fernandes-Pedrosa, M., *Biodegradable cross-linked chitosan nanoparticles improve anti-Candida and anti-biofilm activity of TistH, a peptide identified in the venom gland of the Tityus stigmurus scorpion.* Materials Science and Engineering: C, 2019. **103**: p. 109830.

151. Babu, V.N. and S. Kannan, *Enhanced delivery of baicalein using cinnamaldehyde cross-linked chitosan nanoparticle inducing apoptosis.* International journal of biological macromolecules, 2012. **51**(5): p. 1103-1108.

152. Gadkari, R. R., Suwalka, S., Yogi, M. R., Ali, W., Das, A., & Alagirusamy, R., *Green synthesis of chitosan-cinnamaldehyde cross-linked nanoparticles: Characterization and antibacterial activity.* Carbohydrate polymers, 2019. **226**: p. 115298.

153. Wu, J., Wang, Y., Yang, H., Liu, X., & Lu, Z., *Preparation and biological activity studies of resveratrol loaded ionically cross-linked chitosan-TPP nanoparticles.* Carbohydrate polymers, 2017. **175**: p. 170-177.

154. Bui, T. H., Lee, W., Jeon, S. B., Kim, K. W., & Lee, Y., *Enhanced Gold (III) adsorption using glutaraldehyde-crosslinked chitosan beads: Effect of crosslinking degree on adsorption selectivity, capacity, and mechanism.* Separation and Purification Technology, 2020. **248**: p. 116989.

155. Kausar, A., *Polymer and modified chitosan-based nanocomposite: impending material for technical application.* Polymer-Plastics Technology and Materials, 2019. **58**(9): p. 934-947.

156. Barkhordari, S., Alizadeh, A., Yadollahi, M., & Namazi, H., *One-pot synthesis of magnetic chitosan/iron oxide bio-nanocomposite hydrogel beads as drug delivery systems.* Soft Materials, 2020: p. 1-9.
157. Vaewbundit, S. and P. Siriphannon, *Soft solution in-situ synthesis of chitosan/iron oxide nanocomposites and their magnetic properties.* Soft Matter, 2021.
158. Wulandari, I. O., Mardila, V. T., Santjojo, D. D. H., & Sabarudin, A., *Preparation and characterization of chitosan-coated Fe3O4 nanoparticles using ex-situ co-precipitation method and tripolyphosphate/sulphate as dual crosslinkers*. in *IOP Conference Series: Materials Science and Engineering*. 2018. IOP Publishing.
159. Reghioua, A., Barkat, D., Jawad, A. H., Abdulhameed, A. S., & Khan, M. R., *Synthesis of Schiff's base magnetic crosslinked chitosan-glyoxal/ZnO/Fe3O4 nanoparticles for enhanced adsorption of organic dye: Modeling and mechanism study.* Sustainable Chemistry and Pharmacy, 2021. **20**: p. 100379.
160. Dos Santos, J. M., Pereira, C. R., Pinto, L. A. A., Frantz, T., Lima, É. C., Foletto, E. L., & Dotto, G. L., *Synthesis of a novel CoFe2O4/chitosan magnetic composite for fast adsorption of indigotine blue dye.* Carbohydrate polymers, 2019. **217**: p. 6-14.
161. Regiel-Futyra, A., Kus-Liśkiewicz, M., Wojtyła, S., Stochel, G., & Macyk, W., *The quenching effect of chitosan crosslinking on ZnO nanoparticles photocatalytic activity.* RSC advances, 2015. **5**(97): p. 80089-80097.
162. Farhoudian, S., M. Yadollahi, and H. Namazi, *Facile synthesis of antibacterial chitosan/CuO bio-nanocomposite hydrogel beads.* International journal of biological macromolecules, 2016. **82**: p. 837-843.
163. Liu, Y., Lu, J., Li, M., & He, C., *Characterization and Antibacterial Properties of Genipin-crosslinked Chitosan/TiO2 Nanocomposites.* Polymer (Korea), 2016. **40**(2): p. 1-7.
164. Pincus, L. N., Melnikov, F., Yamani, J. S., & Zimmerman, J. B., *Multifunctional photoactive and selective adsorbent for arsenite and arsenate: Evaluation of nano titanium dioxide-enabled chitosan cross-linked with copper.* Journal of hazardous materials, 2018. **358**: p. 145-154.
165. Hamrayev, H., K. Shameli, and M. Yusefi, *Preparation of zinc oxide nanoparticles and its cancer treatment effects: A review paper.* Journal of Advanced Research in Micro and Nano Engineering, 2020. **2**(1): p. 1-11.

166. Balraj, B., Senthilkumar, N., Siva, C., Krithikadevi, R., Julie, A., Potheher, I. V., & Arulmozhi, M., *Synthesis and characterization of Zinc Oxide nanoparticles using marine Streptomyces sp. with its investigations on anticancer and antibacterial activity.* Research on Chemical Intermediates, 2016. **43**(4): p. 2367-2376.

167. Rajeshkumar, S., Kumar, S. V., Ramaiah, A., Agarwal, H., Lakshmi, T., & Roopan, S. M., *Biosynthesis of zinc oxide nanoparticles usingMangifera indica leaves and evaluation of their antioxidant and cytotoxic properties in lung cancer (A549) cells.* Enzyme and Microbial Technology, 2018. **117**: p. 91-95.

168. Perera, W. P. T. D., Dissanayake, R. K., Ranatunga, U. I., Hettiarachchi, N. M., Perera, K. D. C., Unagolla, J. M., ... & Pahalagedara, L. R., *Curcumin loaded zinc oxide nanoparticles for activity-enhanced antibacterial and anticancer applications.* RSC Advances, 2020. **10**(51): p. 30785-30795.

169. Selim, Y. A., Azb, M. A., Ragab, I., & Abd El-Azim, M. H., *Green Synthesis of Zinc Oxide Nanoparticles Using Aqueous Extract of Deverra tortuosa and their Cytotoxic Activities.* Sci Rep, 2020. **10**(1): p. 3445.

170. Ruddaraju, L. K., Pammi, S. V. N., Pallela, P. V. K., Padavala, V. S., & Kolapalli, V. R. M., *Antibiotic potentiation and anti-cancer competence through bio-mediated ZnO nanoparticles.* Mater Sci Eng C Mater Biol Appl, 2019. **103**: p. 109756.

171. Nilavukkarasi, M., S. Vijayakumar, and S. Prathipkumar, *Capparis zeylanica mediated bio-synthesized ZnO nanoparticles as antimicrobial, photocatalytic and anti-cancer applications.* Materials Science for Energy Technologies, 2020. **3**: p. 335-343.

172. Ngoepe, N. M., Mbita, Z., Mathipa, M., Mketo, N., Ntsendwana, B., & Hintsho-Mbita, N. C., *Biogenic synthesis of ZnO nanoparticles using Monsonia burkeana for use in photocatalytic, antibacterial and anticancer applications.* Ceramics International, 2018. **44**(14): p. 16999-17006.

173. Vidhya, E., Vijayakumar, S., Prathipkumar, S., & Praseetha, P. K., *Green way biosynthesis: Characterization, antimicrobial and anticancer activity of ZnO nanoparticles.* Gene Reports, 2020. **20**.

174. Bai Aswathanarayan, J., R. Rai Vittal, and U. Muddegowda, *Anticancer activity of metal nanoparticles and their peptide conjugates against human colon adenorectal carcinoma cells.* Artif Cells Nanomed Biotechnol, 2018. **46**(7): p. 1444-1451.

175. Yusefi, M., Shameli, K., Ali, R. R., Pang, S. W., & Teow, S. Y., *Evaluating anticancer activity of plant-mediated synthesized iron oxide nanoparticles using Punica Granatum fruit peel extract.* Journal of Molecular Structure, 2020. **1204**: p. 127539.

176. Yadollahi, M., Farhoudian, S., Barkhordari, S., Gholamali, I., Farhadnejad, H., & Motasadizadeh, H., *Facile synthesis of chitosan/ZnO bio-nanocomposite hydrogel beads as drug delivery systems.* Int J Biol Macromol, 2016. **82**: p. 273-8.

177. Zare, M., Namratha, K., Thakur, M. S., & Byrappa, K., *Biocompatibility assessment and photocatalytic activity of bio-hydrothermal synthesis of ZnO nanoparticles by Thymus vulgaris leaf extract.* Materials Research Bulletin, 2019. **109**: p. 49-59.

178. Naseer, M., Aslam, U., Khalid, B., & Chen, B., *Green route to synthesize Zinc Oxide Nanoparticles using leaf extracts of Cassia fistula and Melia azadarach and their antibacterial potential.* Sci Rep, 2020. **10**(1): p. 9055.

179. Mohammad, G. R. K. S., Tabrizi, M. H., Ardalan, T., Yadamani, S., & Safavi, E., *Green synthesis of zinc oxide nanoparticles and evaluation of anti-angiogenesis, anti-inflammatory and cytotoxicity properties.* Journal of Biosciences, 2019. **44**(2).

180. Nourmohammadi, E., Oskuee, R. K., Hasanzadeh, L., Mohajeri, M., Hashemzadeh, A., Rezayi, M., & Darroudi, M., *Cytotoxic activity of greener synthesis of cerium oxide nanoparticles using carrageenan towards a WEHI 164 cancer cell line.* Ceramics International, 2018. **44**(16): p. 19570-19575.

181. Zak, A. K., Majid, W. A., Mahmoudian, M. R., Darroudi, M., & Yousefi, R., *Starch-stabilized synthesis of ZnO nanopowders at low temperature and optical properties study.* Advanced Powder Technology, 2013. **24**(3): p. 618-624.

182. Darroudi, M., Sabouri, Z., Oskuee, R. K., Zak, A. K., Kargar, H., & Abd Hamid, M. H. N., *Green chemistry approach for the synthesis of ZnO nanopowders and their cytotoxic effects.* Ceramics International, 2014. **40**(3): p. 4827-4831.

183. Zak, A. K., Yousefi, R., Abd Majid, W. H., & Muhamad, M. R., *Facile synthesis and X-ray peak broadening studies of Zn1− xMgxO nanoparticles.* Ceramics International, 2012. **38**(3): p. 2059-2064.

184. Fardood, S. T., Ramazani, A., Moradi, S., & Asiabi, P. A., *Green synthesis of zinc oxide nanoparticles using arabic gum and photocatalytic degradation of direct blue 129 dye*

under visible light. Journal of Materials Science: Materials in Electronics, 2017. **28**(18): p. 13596-13601.

185. Goswami, M., N.C. Adhikary, and S. Bhattacharjee, *Effect of annealing temperatures on the structural and optical properties of zinc oxide nanoparticles prepared by chemical precipitation method.* Optik, 2018. **158**: p. 1006-1015.

186. Raleaooa, P. V., Roodt, A., Mhlongo, G. G., Motaung, D. E., Kroon, R. E., & Ntwaeaborwa, O. M., *Luminescent, magnetic and optical properties of ZnO-ZnS nanocomposites.* Physica B: Condensed Matter, 2017. **507**: p. 13-20.

187. Abdullah, S., Azeman, N. H., Mobarak, N. N., Zan, M. S. D., & Bakar, A. A. A., *Sensitivity enhancement of localized SPR sensor towards Pb (II) ion detection using natural bio-polymer based carrageenan.* Optik, 2018. **168**: p. 784-793.

188. Elnashar, M.M. and M.A. Yassin, *Lactose hydrolysis by β-galactosidase covalently immobilized to thermally stable biopolymers.* Applied biochemistry and biotechnology, 2009. **159**(2): p. 426-437.

189. Sukri, S. N. A. M., Shameli, K., Wong, M. M. T., Teow, S. Y., Chew, J., & Ismail, N. A., *Cytotoxicity and antibacterial activities of plant-mediated synthesized zinc oxide (ZnO) nanoparticles using Punica granatum (pomegranate) fruit peels extract.* Journal of Molecular Structure, 2019. **1189**: p. 57-65.

190. Zak, A. K., Majid, W. A., Darroudi, M., & Yousefi, R., *Synthesis and characterization of ZnO nanoparticles prepared in gelatin media.* Materials Letters, 2011. **65**(1): p. 70-73.

191. AbdElhady, M.M., *Preparation and Characterization of Chitosan/Zinc Oxide Nanoparticles for Imparting Antimicrobial and UV Protection to Cotton Fabric.* International Journal of Carbohydrate Chemistry, 2012. **2012**: p. 1-6.

192. Yusefi, M., Chan, H. Y., Teow, S. Y., Kia, P., Lee-Kiun Soon, M., Sidik, N. A. B. C., & Shameli, .K, *5-Fluorouracil Encapsulated Chitosan-Cellulose Fiber Bionanocomposites: Synthesis, Characterization and In Vitro Analysis towards Colorectal Cancer Cells. Nanomaterials 2021, 11, 1691*. 2021, s Note: MDPI stays neu-tral with regard to jurisdictional claims in ….

193. Li, P. C., Liao, G. M., Kumar, S. R., Shih, C. M., Yang, C. C., Wang, D. M., & Lue, S. J., *Fabrication and characterization of chitosan nanoparticle-incorporated quaternized poly*

(vinyl alcohol) composite membranes as solid electrolytes for direct methanol alkaline fuel cells. Electrochimica Acta, 2016. **187**: p. 616-628.

194. Ali, M. E. A., Aboelfadl, M. M. S., Selim, A. M., Khalil, H. F., & Elkady, G. M., *Chitosan nanoparticles extracted from shrimp shells, application for removal of Fe (II) and Mn (II) from aqueous phases.* Separation Science and Technology, 2018. **53**(18): p. 2870-2881.

195. Morsy, M., Mostafa, K., Amyn, H., El-Ebissy, A. A. H., Salah, A. M., & Youssef, M. A., *Synthesis and Characterization of Freeze Dryer Chitosan Nano particles as Multi functional Eco-Friendly Finish for Fabricating Easy Care and Antibacterial Cotton Textiles.* Egyptian Journal of Chemistry, 2019. **62**(7): p. 1277-1293.

196. El-saied, H.A.-a. and A.M. Ibrahim, *Effective Fabrication and Characterization of Eco-Friendly Nano Chitosan Capped Zinc Oxide Nanoparticles for Effective Marine Fouling Inhibition.* Journal of Environmental Chemical Engineering, 2020. **8**(4): p. 103949.

197. Mohammadpour Dounighi, N., Eskandari, R., Avadi, M. R., Zolfagharian, H., Mir Mohammad Sadeghi, A., & Rezayat, M., *Preparation and in vitro characterization of chitosan nanoparticles containing Mesobuthus eupeus scorpion venom as an antigen delivery system.* Journal of Venomous Animals and Toxins Including Tropical Diseases, 2012. **18**: p. 44-52.

198. Behl, G., Iqbal, J., O'Reilly, N. J., McLoughlin, P., & Fitzhenry, L., *Synthesis and characterization of poly (2-hydroxyethylmethacrylate) contact lenses containing chitosan nanoparticles as an ocular delivery system for dexamethasone sodium phosphate.* Pharmaceutical research, 2016. **33**(7): p. 1638-1648.

199. Lustriane, C., Dwivany, F. M., Suendo, V., & Reza, M., *Effect of chitosan and chitosan-nanoparticles on post harvest quality of banana fruits.* Journal of Plant Biotechnology, 2018. **45**(1): p. 36-44.

200. Yang, Y., Song, Z., Wu, W., Xu, A., Lv, S., & Ji, S., *ZnO Quantum Dots Induced Oxidative Stress and Apoptosis in HeLa and HEK-293T Cell Lines.* Frontiers in Pharmacology, 2020. **11**(131).

201. Roshini, A., Jagadeesan, S., Cho, Y. J., Lim, J. H., & Choi, K. H., *Synthesis and evaluation of the cytotoxic and anti-proliferative properties of ZnO quantum dots against MCF-7 and MDA-MB-231 human breast cancer cells.* Materials Science and Engineering: C, 2017. **81**: p. 551-560.

202. Song, Y., Guan, R., Lyu, F., Kang, T., Wu, Y., & Chen, X., *In vitro cytotoxicity of silver nanoparticles and zinc oxide nanoparticles to human epithelial colorectal adenocarcinoma (Caco-2) cells.* Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis, 2014. **769**: p. 113-118.
203. Perera, W. P. T. D., Dissanayake, R. K., Ranatunga, U. I., Hettiarachchi, N. M., Perera, K. D. C., Unagolla, J. M., ... & Pahalagedara, L. R., *Curcumin loaded zinc oxide nanoparticles for activity-enhanced antibacterial and anticancer applications.* RSC Advances, 2020. **10**(51): p. 30785-30795.
204. Wahab, R., Q. Saquib, and M. Faisal, *Zinc oxide nanostructures: A motivated dynamism against cancer cells.* Process Biochemistry, 2020. **98**: p. 83-92.
205. Ruddaraju, L. K., Pammi, S. V. N., Pallela, P. V. K., Padavala, V. S., & Kolapalli, V. R. M., *Antibiotic potentiation and anti-cancer competence through bio-mediated ZnO nanoparticles.* Materials Science and Engineering: C, 2019. **103**: p. 109756.
206. Guan, R., Kang, T., Lu, F., Zhang, Z., Shen, H., & Liu, M., *Cytotoxicity, oxidative stress, and genotoxicity in human hepatocyte and embryonic kidney cells exposed to ZnO nanoparticles.* Nanoscale research letters, 2012. **7**(1): p. 1-7.

LIST OF PUBLICATIONS

Indexed Conference Proceedings

1. **H. Hamrayev**, and K. Shameli. *Biopolymer-Based Green Synthesis of Zinc Oxide (Zno) Nanoparticles*. in *IOP Conference Series: Materials Science and Engineering*. 2021. IOP Publishing. **(IOP Publishing)**

Non Indexed Journal

1. **H. Hamrayev**, K. Shameli, and M. Yusefi, *Preparation of Zinc Oxide Nanoparticles and its Cancer Treatment Effects: A Review Paper.* Journal of Advanced Research in Micro and Nano Engineering, 2020. **2**(1): p. 1-11.
2. **H. Hamrayev**, K. Shameli, and S. Korpayev, *Green Synthesis of Zinc Oxide Nanoparticles and Its Biomedical Applications: A Review.* Journal of Research in Nanoscience and Nanotechnology, 2021. **1**(1): p. 62-74.
3. **H. Hamrayev**, K. Shameli, M. Yusefi, and S. Korpayev, *Green Route for the Fabrication of ZnO Nanoparticles and Potential Functionalization with Chitosan Using Cross-linkers: A Review.* Journal of Research in Nanoscience and Nanotechnology, 2021. **3**(1): p. 1-25.
4. Yusefi, M, K. Shameli, P. Kia, and **H. Hamrayev** et al., *Facile Fabrication of Polysaccharide Nanocomposites Using Ionic Gelation Method.* Journal of Research in Nanoscience and Nanotechnology, 2021. **3**(1): p. 37-45.