engineering proceedings

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Proceeding Paper

Green Synthesis of Zinc Oxide Nanoparticles by Using Pomegranate Peels: An Overview †

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† Presented at the 4th International Electronic Conference on Applied Sciences, 27 October–10 November 2023; Available online: https://asec2023.sciforum.net/.

Abstract: Zinc oxide (ZnO) is a crucial material for industries such as rubber production, biomedical applications, and metal surface treatment areas. ZnO has semiconductivity, antimicrobial activity, and UV absorption capability. This material is regarded as a vulcanization activator. Transform this material to a nanoparticle prefers because increasing the materials particle size decreases and surface area occurs in this way. In scientific literature, researchers have attempted to increase the features of ZnO nanoparticles to use them as a photocatalyst and an antimicrobial agent. Besides that, it studied improving properties of this nanomaterial to use in energy cells and sensors. The synthesis of ZnO nanoparticles in a biological way is accepted as an eco-friendly process. Since hazardous chemicals and high energy are not used, the biological method is called green synthesis. In the synthesis of ZnO nanoparticles via the green route, zinc nitrate or zinc acetate is the source of zinc salt added to biological extracts. These extracts can obtain from algae, plants, and bacteria. The reaction between the salt and extract occurs, then thermal treatment is applied to reach the nanoparticle.

Keywords: ZnO nanoparticles; green chemistry; pomegranate peels

1. Introduction

Nanotechnology term means the control and restructuring of a material at the size of nearly between 1 and 100 nm [1]. Nanotechnology has two approaches: top-down and bottom-up. The aim is to create nanoscale structures from large ones in the top-down approach. In this approach, it desired to obtain a nanomaterial that preserves its initial properties. The purpose is to produce nanomaterials by assembling atoms or molecules in a bottom-up approach [2]. Nanomaterials are classified as carbon-based, metal-based, dendrimer, composite, and ceramics concerning their structure. Besides that, they can be in several forms as nanowires, nanotubes, quantum dots, etc. Because nanomaterials have many crucial features such as electronic, optical, mechanical, and thermo-physical, they have many applications. One of the application areas of nanomaterials is environmental waste management. Thanks to their high surface area/volume ratio, nanomaterials can be used in water treatment as adsorbents. Metallic and metal oxide nanomaterials and carbon nanotubes can be utilized to clean water from contaminants. Besides that, nanomaterials have been used in biomedical areas. For example, carbon-based nanomaterials can be utilized in drug delivery, bio-sensing, bio-imaging, and immobilization of enzymes. In addition, nanomaterials can be used in the food sector to detect food quality. Thanks to Nano-sensors, it can be possible to define pathogens and identify microorganisms in food. However, nanomaterials can be toxic to human life. So nowadays, researchers have developed green synthesis routes to overcome this situation. Green synthesis of nanomaterials is based on using biological extracts instead of hazardous chemicals for surface functionality [3].

Citation: Ozcakir, G. Green Synthesis of Zinc Oxide Nanoparticles by Using Pomegranate Peels: An Overview. *Eng. Proc.* **2023**, *52*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s): Name

Published: date

This study aimed to show the synthesis, properties, and applications of biomass-based nanoparticles specific to pomegranate based ZnO nanoparticles.

2. Biomass Based ZnO Nanoparticles (ZnONPs): Synthesis and Applications

Green synthesis is an environmental-friendly and non-expensive method to produce nanoparticles (NPs). By this method, it can be possible to obtain ZnONPs with high yield and no impurity [4].

Several kinds of inorganic metal oxides like Titanium Dioxide (TiO_2), Copper (II) Oxide (CuO), and ZnO are popular in scientific research. Among them, ZnO has the most eminent inorganic metal oxide because it is concerned as a safe material. ZnONPs have many features. Firstly, its band gap, 3.37 eV, is high. So, the material has high semi-conductivity. Secondly, it has a high exciton binding energy of 60 meV. Applications of ZnONPs are wide. They use in the cosmetic sector due to their UV-protective property. Besides that, biomedical applications are suitable for these. They utilize as anti-cancer, anti-diabetic, and drug delivery. Its antibacterial property is high. In addition, they can use place in several sectors like rubber production, painting, and the adsorption of arsenic from water [4].

Biological synthesis is accepted as a green way to produce ZnONPs in a laboratory. Because the synthesis route based on a few principles of green chemistry that use renewable feedstocks, safer solvents, and obtain safer chemicals. Generally, the synthesis procedure does by adding a zinc salt like zinc nitrate or zinc acetate to a biological extract prepared from fungus, plants, algae, or bacteria. Then, the solution exposes to thermal treatment. Thus, ZnONPs obtain. Parameters that affected the reaction are temperature, time, pH, and concentration of zinc salts [5].

Table 1, it can see various biomass types and applications for ZnONPs.

Table 1. Current biomass based ZnONPs and its applications published in the literature.

Biomass	Application	Reference
Spirogyra hyalina sp. algae	antioxidant and antimicrobial agent	Hameed et al. (2023) [6]
thymus syriacus plant	optoelectronic materials and antibacterial agents	Şahin et al. (2022) [7]
Scoparia Dulcis plant	antioxidant and antimicrobial agent	Sivasankarapillai et al. (2022) [8]
Malva Parviflora plant	preserving food quality for a long time, increasing shelf-life	Iqbal et al. (2022) [9]
mushroom fungus *Cordyceps militaris*	antidiabetic, antioxidant, and antibacterial	Dias et al. (2022) [10]
Dictyota dichotoma endophytic fungi	photocatalytic degradation of fast green dye and antibacterial applications	Kumar et al. (2022) [11]
Orange peels	antibacterial	Thi et al. (2020) [12]

3. Pomegranate Based ZnO Nanoparticles (ZnONPs): Outstanding Features and Applications

The pomegranate is a crucial fruit in the biotechnology field. Its seed, juice, and peels are under investigation for many applications in this area. The importance of this fruit comes from its phenolic composition. Extracts of pomegranate peels have antioxidant, antibacterial, anti-inflammatory, anti-ulcer, and anticancer activity [13]. Besides that, it knows that after it consumes, two third of the pomegranate fruit is thrown away as waste [14]. So, selecting pomegranate peel as a feedstock for synthesis NPs is crucial to waste management. Up to date, pomegranate peels can use for the synthesis of several metallic nanoparticles that are Zirconium (Zr) [15], Silver (Ag) [16], Selenium (Se) [17], Gold (Au) [18], Iron (Fe) [19], and Platinum (Pt) [20]. Besides that, there is so much research about Pomegranate Based ZnO Nanoparticles. Table 2, it can see the applications and zinc salt types for the synthesis of these materials. In Figure 1, the synthesis process of

pomegranate-based ZnONPs is displayed. Phenolic compounds in pomegranate peel extract (PPE) like gallic acid, ellagic acid, and punicalagin change the color of zinc salt solution. This color change occurs due to the reduction effect of these phenolics.

Table 2. Current pomegranate based ZnONPs and its applications published in the literature.

Zinc salt	Application	Reference
zinc acetate dihydrate ($C_4H_6O_4Zn{\cdot}2H_2O$)	UV protective properties of a cotton textile	Verbič et al. (2021) [21]
zinc nitrate hexahydrate ($Zn(NO_3)_2{\cdot}6H_2O$)	Antibacterial, antifungal, cytotoxicity, and anticancer activity	Hashem and El-Sayyad (2023) [22]
zinc acetate dihydrate ($C_4H_6O_4Zn{\cdot}2H_2O$)	Antibacterial activity	Abdelmigid et al. (2022) [23]
Zinc chloride ($ZnCl_2$)	removal of cephalexin (CEX) from aqueous solutions	Rashtbari et al. (2020) [24]

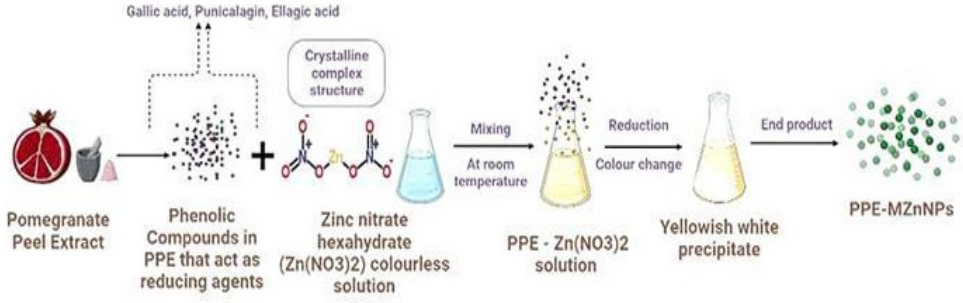

Figure 1. Synthesis of ZnONPs by using pomegranate peel extract. Reprinted with permission from Ref. [13].

4. Conclusion and Remarks

Green chemistry has gained importance due to global warming issues. Biological synthesis is a green and feasible way to synthesize metallic nanoparticles. ZnO nanoparticles have semi-conductivity and UV-filtering properties. According to the literature, the synthesis of ZnO nanoparticles by using pomegranate peels is a novel topic. Pomegranate peels have importance mainly in the biomedical area. This research concluded that researchers can try several fruit peels to synthesize ZnONPs. In addition, several metallic salts can be used for pomegranate peels to obtain NPs. Besides, there is scarce information about computational studies on this topic. Also, catalytic activity in several reactions can be worked with pomegranate-derived ZnONPs.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

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