Review Article

Biosynthesis of Zirconium Oxide Nanoparticles from Different Plant Extracts: A Review

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Abstract:

In this review article, we summarized the green synthesis method for metal nanoparticles, and ecological friendly methods for fabricating metal oxide NPs, because of their great biodegradable, electrical, mechanical, and optical qualities. Zirconium oxide has piqued the interest of researchers throughout the world, particularly since the development of methods for the manufacture of Nano-sized particles. An extensive study into the creation of nanoparticles utilizing various synthetic techniques and their potential uses has been stimulated by their high luminous efficiency. Zirconium dioxide nanoparticles may be used as antimicrobial and anticancer agents in food packaging; developed methods for synthesizing nanoparticles, with various morphologies have recently been created using biological (green chemistry) methods. Different natural Photo constituents exist in plant extracts such as polysaccharides, proteins, polyphenols, enzymes, vitamins, and steroids are responsible for the formation and stabilization of zirconium dioxide nanoparticles. Zirconium nanoparticles are receiving diverse biomedical applications because of their distinctive antimicrobial, antioxidant, anticancer, antifungal, It is possible to analyze the nanoparticles produced using a variety of analytical approaches, including ultraviolet-visible spectroscopy, X-ray diffraction, transmission electron microscopy, and Fourier transform infrared spectroscopy.

Keywords: Biomedical Applications, Biological Synthesis, X-ray diffraction, Zirconium Nanoparticles.

1. Introduction

Last few year's nanotechnology is showed tremendously and is one of the wonderful one branches of science [1- 3] because of its important applications in different in various fields which includes, food technology, health care, mechanics, electrochemistry, sensors, biomedicine, synthetics chemistry, cosmetics, catalysis, agriculture, pharmaceutics, optics, [4-6]. Nanoparticles have different applications zirconium dioxide nanoparticles have numerous applications in different fields and It has attracted the attention of the researchers because of its stimulating properties which include catalytic, sensing, mechanical, thermal, electrical, biocompatible, and optical characteristics and due to these characteristics ZrO_2 NPs are utilizing in the various bone implants solar cells, gas sensor, fuel cell, seed germination, photo-catalysis, refractory and energy [3],because physicochemical properties zirconium dioxide nanoparticles possess excellent anticancer, antifungal, antibacterial, and antioxidant properties [4-6]. Zirconium dioxide nanoparticles owns three monoclinic crystal phases (m-zirconium dioxide) phase which is stable at room temperature, and the tetragonal (t-zirconium dioxide) phase present in the temperature range of 1100-2370°C and the cubic (c-zirconium dioxide) phase which is stable above 2370°C temperature [7]. Currently green chemistry via biological approach got much attention from the researcher for the synthesis of metal nanoparticles and the method are environmentally friendly to prepare the nanoparticles which are the safest method [8]. That's why the green synthesis method is safe to prepare metal nanoparticles and also eco-friendly [9, 10]. Lead this using the chemical method for the preparation of nanoparticles generates various environmental poisonous chemicals which are dangerous for both environment and humans [11, 12]. The chemical method is expensive so it's the need of today's science to develop other better alternative approach to synthesize nanoparticles and the green nanotechnology approach are of the best alternative approaches to synthesize different metal nanoparticles in this method use various plant extract[13-16], other waste materials and fruits for the making of nanoparticles which efficiently decrease the use and production of poisonous chemicals [17]. In this review, we aim to focus on the biological preparation, the characterization, and some biological applications of zirconium dioxide nanoparticles.

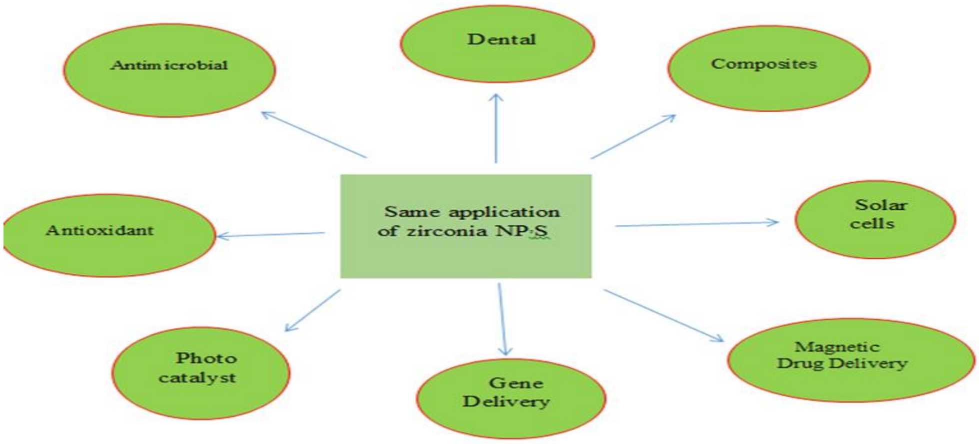

Figure 1. General applications of zirconium Nanoparticles

2. Green Synthesis of Zirconium Dioxide NPs (Biological Methods)

There are physical and chemical methods have disadvantages which include releasing a highly toxic chemical into the environment which is toxic the ecosystem, time-consuming, expansive, and also require high energy consumption. To control these issues green approaches are also applicable the preparation of nanoparticles. As compared to the traditional method the green-mediated approach has a lot of advantages which are biocompatible, ecofriendly, and more important [18, 19]. In the method, various plants/ parts of plants are used for the preparation of nanoparticles also using fruits, fungi, bacteria, algae, and other biological molecules include egg albumin and starch which are acting as capping/ reducing/ and oxidizing agents [20, 21].

3.1. Green Synthesis Using Plant Extracts

In Nano biotechnology using green approaches for the preparation of metal oxide nanomaterial is an emerging field of research in this time and the importance of this method over the chemical/physical method is that this approach is safe facile swift cost-effective and also can easily produce a large scale of NPs and also utilizing this approach no requirements of energy, pressure, increase temperature and toxic chemical [6, 22]. Utilizing plant material for the preparation of zirconium dioxide nanoparticles got much attention because of the simple, nontoxic, rapid environmentally safe, cost-effective, and easy one-step process to prepare NPs [22, 23]. The plants contain various combinations of biomolecules that help in the stability of ZrO_2 nanoparticles these biomolecules include tannins, sugar, steroid, enzymes, phenols, amino acids, flavonoids, and sugar which are mostly present in plants extracts and important for the medicinal purpose [24, 25]. Various plants are reported for the preparation of zirconium nanoparticles and mentioned in this review. In a recent study, *AcalyphaIndica* aqueous leaf extract is used for making zirconium dioxide NPs and the average size of the prepared NPs have observed 20-100nm [26]. Similarly, Camellia oleifera (C. oleifera) seed shells are used to prepare zirconium dioxide/biochar. The prepared materials have an excellent ability to absorb of fluoride in water [27]. *Nyctanthes arbor-tristis* flower extract-based zirconia nanoparticles are reported and due to the presence of water soluble carbohydrates nano-sized zirconium dioxide nanoparticles are prepared [28]. Further adsorptive properties are tested against tetracycline antibiotics and the prepared nanoparticles are characterized through TEM. FTIR and XRD techniques revealed that synthesize material has a minimum crystallite size of 5.25nm [29]. Similarly, rubber latex is utilized for the making of zirconium NPs and the prepared nanoparticles have a tetragonal structure [30]. Wrightiatinctoria leaf extract is exploited for the preparation of zirconium dioxide nanoparticles to determine the anti-bacterial and phot-catalyst activity of the nanoparticles [31]. Curcuma longa tuber-based zirconia nanoparticles are prepared and the water-soluble organic is responsible for the preparation of NPs which convert ZrF_6^{2-} ions to ZrNP and the average size of the nanoparticles are confirmed 41-45nm [32].

3.2. Fungal Mediated Synthesis of Zirconium Dioxide Nanoparticles

Microorganisms are used in green nanotechnology to synthesize nanoparticles (NPS). Many microorganisms are known to accumulate inorganic compounds inside or outside the cell to synthesize nanoparticles. Whereas many microbial species can produce metal NPs and microbial NP production is a green chemistry strategy that fills the gap between nanotechnology and microbial biotechnology and many studies reported that bacteria, actinomycetes, fungi, yeasts, and viruses can produce Au, Ag, gold alloy, selenium, tellurium, platinum, palladium, silica, titania, zirconia, quantum dots (QDs), magnetite, and uraninite NPs [33]. ZrO_2 NPs are prepared using Penicillium species as a dependable and environmentally friendly procedure [34]. Fusariumsolani, a Phyto-pathogenic fungus, are utilized for making of zirconium oxide (ZrO_2) nanoparticles which acts as a reducing and stabilizing agent. [35], the fungus Fusariumoxysporum can be challenged with aqueous ZrF_6 22 anions to produce zirconia nanoparticles; extracellular protein-mediated hydrolysis of the anionic complexes results in the facile room-temperature synthesis of nanocrystalline zirconia. [36]. The total protein content activity was used to evaluate the ability for zirconium nanoparticle (Zr-NP) biosynthesis in various stages of growth of *Penicilliumnotatum*, *P. purpurogenum*, and *P. aculeatum*. Fungal secreted protein concentrations were greater in all three species during the deceleration phase. [37].

3.3. Bacterial Mediated Synthesis of Zirconium Nanoparticles

Bacteria have significant capabilities to reduce heavy metal ions and could be used to produce nanoparticles. Metal, metal oxide, and other novel nanoparticles were synthesized using various bacterial species [38]. Pseudomonas aeruginosa bacteria are utilized to prepare zirconia NPs using green technology for adsorption-driven bioremediation of tetracycline from wastewater. [39]. ExtremophilicAcinetobacter sp. KCSI1, are utilized for the preparation of crystalline ZrO_2 nanoparticles [40]. PestalotiopsisVersicolor is a highly damaging fungus that causes bayberry twig blight disease. [41]

4. Biomedical Application

4.1. Antibacterial Activity of Zirconia NPs

Bacterial resistance is increasing nowadays is most challenging to produce novel antibiotic agents to treat bacterial diseases and among the novel antibiotic agents, metal nanoparticles showed improved antibacterial performance against bacteria. As bacterial resistance are increasing in a short period so developing novel antibiotic are challenging and released to the market. As nanoparticles have improved antibacterial performance a lot of nanoparticles are developing against bacteria because the nanoparticles target various biomolecules of the resistant strain [42]. Also, bacterial and fungal activities of zirconia and zirconia mixed ligand are reported and the results revealed that zirconia has excellent activity against *E. coli* and also the Zr(Iv) complexes showed excellent performance against both gram-positive *S. aureus* and gram-negative *E. coli* and also displayed excellent performance against *A. niger* fungus[43-45]. Zirconium oxide Nano powder has improved antibacterial performance and the antibacterial activity of the prepared doped oxide is determined against B. subtilis and K. pneumonia which showed improved bactericidal efficiency as compared with undoped oxide [46].

4.2. Antifungal Activity of Zirconium NPs

Fungi are creating destruction of crop productivity and also human pathogenic fungi also cause problems in human evolution due to their presence in any habitat. Due to encrypting gene rearrangement and easy adoption in any environment showing resistance to traditional fungicides so to minimize this issue an effective and immediate strategy is needed to overcome this problem [47]. Recently Zirconium dioxide nanoparticles are prepared against Rhizoctoniasolani to develop root resistance in cucumber. [48]. Zirconium oxide-Ag_2O nanoparticles- synthesized through the sol-gel method showed excellent antifungal activities against various fungus species. [49].

4.3. Anticancer Activity of Zirconium NPs

Cancer is one of the most death-causing diseases which are mostly caused due to mutation in proto-oncogenes expression patterns, in those genes which are involved in DNA repairs and tumor suppresser genes. The disease-causing a high number of deaths worldwide and according to the National cancer institute, fourteen million new cancer cases are reported in 2012, and also 8.2 million cancer-causing deaths are reported [50]. Recently zirconium nanoparticles are synthesized from lemon and lemon peel with zirconium salt further the prepared nanoparticles are tested against MCF-7 cancer cell lines and also tested its bioactivity against free radicals [51]. Zirconium dioxide nanoparticles coated with platelet membrane (PLTm) named PLT@ZrO_2 are synthesized and the prepared PLTmnano vesicles camouflage zirconium dioxide nanoparticles have an efficient ability to target tumor sites and are easily able to clear by macrophages. [52].

5. Conclusion

This review describes the biological preparation of Zirconium nanoparticles and their numerous applications in biomedical science. Therefore special attention is required of the scientific community because this method is a more simple, nontoxic environmentally friendly, and commercially viable approach for the preparation of Zirconium oxide NPs using green chemistry bottom to top approach and using plant extract materials potentially effective over chemical method. Therefore in the future era, more works will be exploited to use this green approach for the preparation of metal oxide NPs because this method is safe and reduce the cost of chemicals. Therefore, further work is needed to use plant parts to develop zirconium oxide nanoparticles and explore their biomedical applications

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