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Green Synthesis and Characterization of Zinc Oxide Nanoparticles using Cow Urine as a Reducing and Stabilizing Agent

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ABSTRACT

Present findings are focusing on an eco-friendly approach for the synthesis of zinc nanoparticles, which emphasizing on nonhazardous chemicals as well as cost-effectiveness. Zinc acetate was used as metal part and locally available indigenous cow urine was utilized for reduction and also as capping agent. Reduction process of zinc ions into nanoscale particles was confirmed by the slightly colour change when cow urine used as reducing agent in the reaction mixture. Further characterization of synthesized nanoparticles was done by UV-Visible spectroscopy, X-ray diffraction and scanning electron microscopy to validate the morphological and structural characteristics. The synthesized nanoparticles were ranging below the size of 100 nm as per the observation. This green synthesis method helps to reduce its negative impacts on the environment and encourages the use of biological waste materials. This technique produces zinc nanoparticles with a variety of possible uses, such as biological, catalytic, and antibacterial ones.

1. Introduction

Nanotechnology has become one of the fastest-growing areas in modern science, due to its diverse applications across fields such as medicine, agriculture, electronics, energy, and environmental protection. Nanoparticles, generally ranging between 1 to 100 nm in size, which shows unique physicochemical properties compared to bulk materials, including a high surface area-to-volume ratio, increased reactivity, and optical and electrical characteristics that depend on their size [1, 2]. With these unique characteristics, nanoparticles are well-suited for use in advanced technologies and biomedical fields. Amid various metal oxide nanoparticles, zinc oxide nanoparticles have strong optical, photocatalytic catalytic and antimicrobial properties as well as having chemical stability and are biocompatible where the synthesis was carried out by employing zinc acetate as a precursor [3, 4]. There is a common acceptance of applications of zinc oxide (ZnO) nanoparticles in different fields as cosmetics formulations, sunscreens, sensor-based technologies, drug delivery, and antimicrobial activities [5].

Conventionally chemical and physical methods are used for the synthesis of zinc oxide nanoparticles. These methods are chemical precipitation, vapour deposition, sol-gel and hydrothermal processing. Though these techniques are effective for the good control over the shape and size of the particle, its energy requirement is high, it involve toxic reagents and require expensive equipment. Chemical and physical methods produce harmful by products, which adversely affect human health and environment [6, 7]. To avoid harmful impacts and reduce the cost of production, environment friendly synthesis methods are encouraged.

In green synthesis method, natural materials like animal derived substances, plant extract enzymes and microorganisms are used as reducing and stabilizing agents which are sustainable and environment friendly [8, 9]. Organic materials like plant metabolites, proteins, amino acids, phenolic compounds and enzymes present in natural sources helps to convert metal ions into nanoparticles while keeping them stable [10].

One of the cost effective and easily available bio resource is cow urine which has traditional importance in Indian medicine and agriculture. Scientific studies have shown that, it contains biologically active compounds like uric acid, Urea, creatine, phenolic substances, volatile fatty acids, and various minerals and enzymes. These substances are effective in reduction, chelating and stabilizing during the synthesis process of

nanoparticles [11, 12]. In past few years, cow urine has grabbed the attention as green and sustainable reagent for synthesizing nanoparticles for metals and metal oxides, such as zinc oxide, due to its rich biochemical composition [13, 14].

Several studies have shown that ZnO nanoparticles can be successfully synthesized using bovine-derived materials like cow urine and cow dung extracts and highlighted their potential for converting waste into valuable nanomaterial [13, 15]. The studies on zinc nanoparticles using cow urine as reducing agent and zinc acetate as the precursor and analysis of their physicochemical properties are still limited, there are lots of findings yet to be done.

This present study is aiming to synthesize the zinc oxide nanoparticles by using zinc acetate and cow urine through a cost effective, ecofriendly and simple approach. Morphological characteristics and the crystalline structure of the particles were examined using UV-visible spectroscopy, X-ray diffraction (XRD) and scanning electron microscopy (SEM).

2. Experimental Methods

2.1 Materials

Zinc acetate dihydrate $[Zn(CH_3COO)_2 \cdot 2H_2O]$ of analytical grade obtained from a standard chemical supplier was used as a precursor for the synthesis of zinc oxide nanoparticles. Collection of fresh cow urine was done from healthy indigenous cow breed from local dairy farm, which then acts as a natural reducing and capping agent for the synthesis of nanoparticles. Glassware was thoroughly washed with the distilled water, and also used throughout the experiments.

2.2 Collection and Preparation of Cow Urine

Cow urine was collected in early in the morning, and the container was used for the collection was sterilized before use. The collected urine sample was then filtered with the help of Whatman No.1 filter paper to remove any debris and suspended particles in the urine sample. The filtered urine sample was then stored for 24 hours at 4 °C to preserve its biochemical characteristics.

2.3 Synthesis of ZnO Nanoparticles using Green Synthesis Method

2.195 g of zinc acetate dihydrate was dissolved in 100 mL of distilled water to prepare an aqueous solution of zinc acetate. Then 20 mL of filtered cow urine was added drop-wise into the reaction mixture by

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stirring the solution continuously. After mixing the solution, it was kept at 80 °C under continuous stirring for 3 hours in alkaline conditions which facilitate the synthesis of nanoparticles. Appearance of visible precipitate along with colour change of the mixture solution indicate the formation of nanoparticles. Then the formed precipitate was centrifuged at 9000 rpm for 10-15 min, after centrifugation the precipitate was treated with distilled water to remove the impurities and later dried. At the end of the procedure, the dried material was calcined at 450 °C for 2 hours to obtain the zinc oxide nanoparticles.

2.4 Characterizations Techniques

Synthesis of ZnO nanoparticles was confirmed with the help of UV-visible spectroscopy (Shimadzu UV-1800) by observing the absorption spectra in the range between 200-800 nm. The average crystalline size and the structure of the nanoparticles was analyzed with the help of X-ray diffraction (XRD) (Rigaku Miniflex 600), Morphology of the surface and size of the particle were studied by scanning electron microscopy (SEM) (FEG-SEM) (JEOL, Japan).

3. Results and Discussion

3.1 Visual Inspection and ZnO Nanoparticles Formation

Initially visual observation helps to confirm the formation of zinc oxide nanoparticles. After the addition of cow urine into the solution of the zinc acetate under continuous stirring, colour change has observed colorless to pale yellow and also leads into formation of white precipitate which indicate the reduction of zinc ions and formation of zinc oxide nanoparticles. Colour change of sample is due to the nucleation and growth of ZnO nanoparticles which is facilitated by the bio component present in cow urine, which acts for reduction and stabilization.

3.2 UV-Visible Spectroscopy Analysis

Fig. 1 is showing the UV-visible absorption spectrum of synthesized ZnO nanoparticles. Absorption peak was observed around 366 nm, which resembling the intrinsic band gap of absorption of zinc oxide nanoparticles. ZnO nanoparticles exhibit absorption peaks between 360 and 380 nm according to the reports on green synthesis methods. This peak indicates the successful formation of ZnO nanoparticles [13, 14]. There may be small shift in the peak position due to the variations in particles size and interaction with other biomolecules located on the surface.

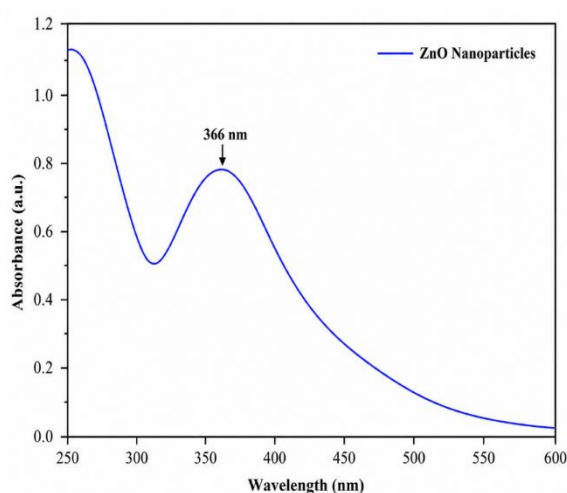


Fig. 1 UV-Visible spectrum of zinc oxide nanoparticles showing absorption peak at 366 nm

3.3 X-Ray Diffraction (XRD) Analysis

The X-ray diffraction configuration of the synthesized ZnO nanoparticles (Fig. 2) exhibited clearly visible diffraction peaks at 2θ values of around 31.7°, 34.4°, 36.2°, 47.5°, 56.6°, 62.8°, 67.9°, and 69.1°, related to the (100), (002), (101), (102), (110), (103), (112), and (201) planes of hexagonal wurtzite ZnO structure in accordance with JCPDS card no. 36-1451. The observed strong and prominent peaks verified the crystallinity and purity of the prepared ZnO particles. The mean crystallite size was calculated using the Debye-Scherrer equation and found to be 24.6 nm.

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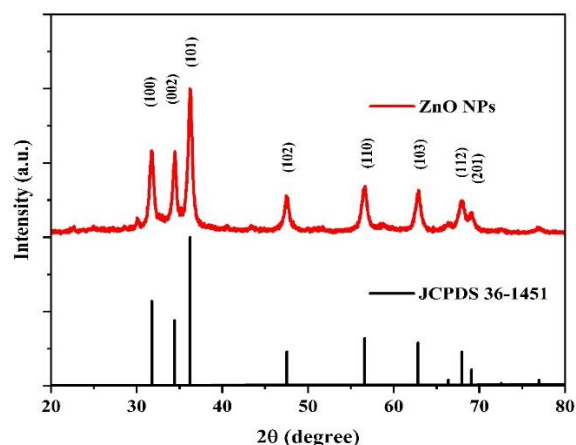


Fig. 2 X-ray diffraction (XRD) pattern of green synthesized ZnO nanoparticles

The lack of additional peaks indicates that the ZnO nanoparticles are phase-pure. Similar crystallite sizes have also been reported for ZnO nanoparticles synthesized through green methods using bovine and plant extracts [11, 15].

3.4 SEM Analysis

SEM images (Fig. 3) revealed that the synthesized ZnO nanoparticles exhibit predominantly spherical / quasi-spherical morphology with slight agglomeration. Agglomeration is often observed due to the high surface energy of nanoparticles and the attractive forces between them. Similar morphological features have also been reported in ZnO nanoparticles synthesized through green methods in earlier studies [3, 5].

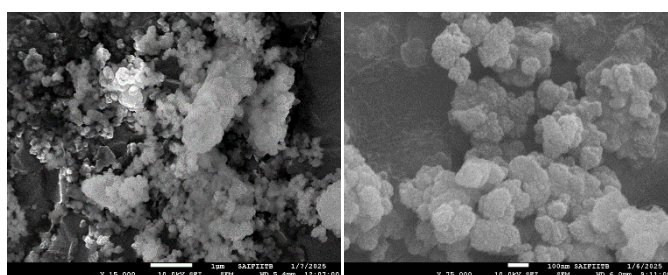


Fig. 3 Representative SEM micrographs demonstrating the surface morphology and particle size distribution of ZnO nanoparticles synthesized via a green approach

4. Conclusion

The present investigation successfully revealed the cost-effective ecofriendly method which is using cow urine as reducing and stabilizing agent for the synthesis of zinc oxide nanoparticle. Characterization studies which were done by the UV-visible spectroscopy, X-ray diffraction (XRD), and scanning electron microscopy (SEM). All these validated the successful synthesis of ZnO nanoparticles which exhibited the crystalline wurtzite structure. The absorption peak of UV recorded around 366 nm and 24.66 nm average crystallite size confirms the nanoscale size of synthesized particles. SEM analysis the shown the synthesis of uniformly distributed nanoparticles with different morphological features. Green synthesis route avoided the use of toxic chemicals and also helps in cost reduction, ecofriendly and sustainable development of nanotechnology. The various desirable phytochemical properties of synthesized ZnO particles suggesting their potential applications in antimicrobial, catalytic, biomedical and various environment filed. The present study emphasizes the importance of ecofriendly nanoparticles and biological resource in developing nanoparticles which supports the advancement in ecofriendly and sustainable nanotechnology.

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