# Eco-Friendly Synthesis of Zinc Oxide Nanoparticles Using Garlic Skin Extract: A Cost-Effective and Sustainable Approach

**Hajrah Ali[*1], Rabia Ali[2]**

[1]Department of Chemistry, Riphah International University Faisalabad

[2]Department of Chemistry, University of Agriculture, Faisalabad

## ABSTRCT

The utilization of plant-mediated synthesis for metal oxide nanoparticles presents a promising alternative to conventional physical and chemical synthesis methods. This study focuses on the biological synthesis of Zinc Oxide nanoparticles (ZnO nanoparticles) using *Allium sativum* skin extract, specifically from garlic skin. The confirmation of ZnO nanoparticle formation was established through UV-visible spectroscopy and FTIR analysis. UV-Vis spectroscopy verified the synthesis of ZnO nanoparticles, exhibiting an absorption peak at 370 nm. These ZnO nanoparticles, synthesized with garlic skin extract, hold potential applications in various fields such as biotechnology, biomedical, catalysis, coatings, sensors, and water remediation. This research highlights an efficient, cost-effective, simple, innovative, eco-friendly, safe, and convenient approach for the green synthesis of multifunctional ZnO nanoparticles.

*Keywords: Green synthesis, ZnO Nanoparticles, Allium sativum, Eco-friendly*

## INTRODUCTION

The nanomaterial's synthesis contribute to the rapid advancement of nanoscience and nanotechnology [1]. Nanotechnology finds applications in diverse fields such as electronics, medicine, energy, materials science, and environmental science [2]. Among nanomaterials, metal oxide nanoparticles have garnered significant attention due to their size-dependent unique properties, including high chemical stability, a high electrochemical coupling coefficient, broad radiation absorption range, high photo stability, easy availability, low cost, and non-toxicity [3].

Zinc Oxide Nanoparticles, derived from garlic extract, demonstrate the adaptability of nanomaterial synthesis [4]. The scientific name of garlic is *Allium sativum*, a widely recognized herb globally. This perennial plant, often grown as an annual, produces edible bulbs composed of individual cloves [5]. Zinc Oxide (ZnO) itself is an inorganic compound with notable properties in various applications [6].

The green synthesis of Zinc Oxide Nanoparticles results in a white powder that is insoluble in water. In the realm of material science, ZnO is recognized as a II-IV semiconductor [7]. This study specifically concentrates on the synthesis of ZnO nanoparticles utilizing garlic skin extract as a reducing agent and Zinc chloride as a precursor for zinc [8]. Notably, garlic skin, often discarded as waste after collecting garlic cloves, was collected for this process [9]. The extracted garlic skin biomass also holds the potential for separating cellulose, lignin, and other components [10].

Benefiting from the increased surface area and activity of the nanoscale ZnO compound, it demonstrates the capability to enhance the efficiency of both aqueous and organic solvents [11]. Additionally, ZnO nanoparticles synthesized through this biological approach prove to be non-toxic and skin-compatible, making them suitable for applications involving contact with the human body [12].

Various methods, such as hydrothermal, sol−gel processing, spray pyrolysis, precipitation, chemical vapor deposition (CVD), and green synthesis, can be employed for synthesizing ZnO nanoparticles (NPs) [13]. The green synthesis method, utilizing plant extracts, is particularly favored among these techniques. This preference arises from its eco-friendly nature, cost-effectiveness, and the non-toxicity of the resulting nanoparticles, making them suitable for human therapeutic applications [14].

In the course of this investigation, ZnO nanoparticles were synthesized using Allium sativum skin (garlic skin) extract. Confirmation of ZnO nanoparticle formation was achieved through various analytical techniques, including UV-visible spectroscopy, UV diffuse reflectance spectroscopy (UV-DRS), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), Scanning Electron Microscope (SEM) with Energy Dispersive X-ray studies (EDX), transmission electron microscope (TEM), Atomic Force Microscopy (AFM), BrunauerEmmet-Teller (BET), and Thermo gravimetric analysis (TGA). The UV-Vis spectroscopy verified the synthesis, displaying a characteristic absorption peak at 370 nm. SEM and TEM analyses further confirmed the formation of rod and hexagonal-shaped nanoparticles with an average size of 7.77 nm.

## MATERIAL AND METHOD

The synthesis involved the use of various materials and chemicals. Materials included a fresh ginger root (Z. officinale), garlic bulb (*Allium sativum*), beaker, magnetic stirrer, hot plate, incubator, power supply, thermometer, Whatman No. 1 filter papers, digital electronic analytical balance, furnace, ceramic crucible cups, drying oven, cylinders, and a centrifuge with a maximum RPM of 5,000.

Chemicals used comprised zinc acetate (Zn(CH3COO)2·2H2O) with a molar mass of 219.49g/mol, deionized water, ethanol, sodium hydroxide (NaOH), and dimethyl sulfoxide

(DMSO, (CH3)2OS, 99.9% pure). Zinc acetate dehydrate served as a precursor, and sodium hydroxide was employed for pH control. All reagents used in the experiments were of analytical grade and utilized without further purification.

**Preparation of garlic skin extract**

The collected garlic skins underwent thorough washing with tap water and subsequent rinses with distilled water. Subsequently, the skins were dried at 40°C in an oven for seven days, followed by the preparation of powder. A 10-gram portion of this garlic skin powder was immersed in a 250 ml Erlenmeyer flask containing 100 ml of 80% ethanol. The solution underwent heating at 60°C for 20 minutes and was stirred using a magnetic stirrer for 24 hours. The resulting extract was filtered through Whatman filter paper No.1 at room temperature. For nanoparticle synthesis, 50 ml of the filtrate was utilized, while the remaining portion was subjected to evaporation in a rotary evaporator at 45°C until completely dry. The evaporated extract was stored at 4°C. Qualitative and quantitative analyses of the garlic skin extract were performed using standard methods.

**Zinc Oxide nanoparticle's synthesis**

A 200 ml solution of 2 mM zinc chloride was prepared and stirred for 20 hours. During the study, pH optimization revealed that the best synthesis occurred at pH 8. Consequently, the solution's pH was adjusted to 8 using a 1 M NaOH solution. Subsequently, 30 ml of garlic skin extract solution was added drop wise to the adjusted solution under constant stirring. The color of the reaction mixture changed after 30 minutes of incubation time. The solution was left stirring for an additional 4 hours after confirming the synthesis of ZnO nanoparticles.

The obtained precipitate underwent separation from the reaction solution through centrifugation at 7000 rpm for 15 minutes. It was washed multiple times with distilled water, followed by ethanol, to eliminate organic impurities. The resulting pellet was collected, dried using a hot air oven at 80°C overnight, and preserved in airtight bottles for subsequent characterization studies.

**Characterization techniques**

The instruments employed for Zinc Oxide Nanoparticle (ZnO NP) characterization included X-ray diffraction (XRD) with Cu–Kα radiation, operating at 40 kV with a scanning rate of 3° $min^{-1}$, recording in the 2θ range between 10° and 80°. XRD was utilized to investigate the crystal structure of the nanoparticles [15]. Additionally, UV–visible spectroscopy measured the energy band gap, photoluminescence (PL) spectroscopy determined the emission spectra, and FTIR spectroscopy characterized the functional groups attached to the synthesized ZnO nanoparticles [16].

## RESULTS AND DISCUSSIONS

The FTIR study aimed to identify potential bioactive biomolecules and protein functional groups participating in ZnO nanoparticle (ZnONP) formation. The recorded FTIR spectra of ZnONPs spanned the wavenumber range of 500–4000 cm−1. Notably, the spectra exhibited a broad peak at 3318 cm−1, attributed to -OH stretching vibrations. Additionally, a sharp peak at the wavenumber 1637 cm−1 was observed, corresponding to C=C alkenes in the aromatic ring.

UV–Vis spectroscopic analysis serves as an effective and qualitative tool for detecting the presence of metal nanoparticles. The optical properties, specifically the lambda max (λmax) of synthesized ZnO nanoparticles (ZnONPs), were characterized using UV–Vis spectroscopy within the wavelength range of 300 to 600 nm. The absorption peak (λmax) was recorded at 300 nm, signifying the characteristic surface Plasmon resonance of the produced metal nanoparticles. The presence of phenolic and flavonoids in A. sativum extract is noteworthy, playing a crucial role in the reduction and synthesis of metal ions into metal nanoparticles.

## CONCLUSIONS:

In conclusion, this study establishes that zinc oxide nanoparticles can be successfully synthesized from A. sativum extract, offering an inexpensive, eco-friendly, and chemical-free alternative. In comparison to conventional physical and chemical methods, which involve adverse effects such as high temperature and pressure conditions, the use of expensive and toxic chemicals, prolonged reflux reaction times, and the production of toxic by-products, the synthesis using garlic skin extract proves advantageous. FTIR analysis revealed the association of various functional groups with ZnO nanoparticles, and UV-Vis spectroscopy demonstrated the energy absorption characteristics of the nanoparticles. Overall, this method proves to be an economical approach for ZnO nanoparticle synthesis, considering factors such as energy efficiency, time, simplicity, cost-effectiveness, and environmental friendliness.

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