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Research Article

Green Synthesis of ZnO Particles Using Jasmine Tea Extract from Commercial Tea Bags

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ABSTRACT

Zinc oxide (ZnO) refers to an inorganic compound functioning as a semiconductor, recognized for its wide-ranging potential and current usage in multiple domains, such as for antibacterial purposes. The formation of zinc oxide using commercial jasmine tea has become an attractive alternative, due to its abundant phenolic constituents with strong antioxidant activity. This thereby facilitates the green synthesis of ZnO. This study synthesized ZnO particles with zinc acetate as the starting material and jasmine tea extract derived from commercial teabags acting as the reducing agent in two ratio variations (Z1 and Z2). The produced particles underwent characterization via XRD, SEM-EDX, and PSA. Their antibacterial activity was evaluated using a microdilution method to find the MIC point. The result showed that both ZnO particles adopt a wurtzite crystal, and the morphology possesses a round morphology with an estimated diameter of 500 nm. Antimicrobial potency testing was additionally performed on *S. aureus* and *E. coli* with an MIC value of 1000 ppm.

Keywords: Antibacterial, Green Synthesis, Jasmine Tea Extract, Zinc Oxide

1. Introduction

Zinc oxide belongs to the category of inorganic compounds and functions as a semiconductor. It has the ability to crystallize into three structures: wurtzite, zinc blende, and rocksalt [1]. At typical room conditions of temperature and pressure, the wurtzite structure remains the most stable arrangement. Within this lattice, each zinc ion is bonded to four oxygen ions arranged in a tetrahedral geometry. Zinc oxide possesses a large energy band gap between 3.1 and 3.3 eV, enabling its application in various sectors such as biosensing, skincare, and pharmaceutical delivery. It is non-toxic, bio-safe, and compatible with human tissue. Moreover, zinc oxide demonstrates abilities to suppress tumor cells, ease inflammation, and inhibit microbial activity [2][3].

Numerous techniques have been employed to synthesize ZnO, such as precipitation, hydrolysis using polyol media, application of polymer-originated precursors, gas-phase condensation, pyrolysis through aerosol spraying, hydrothermal procedures, sol-gel methodology, and decomposition via microwave heating in solid-state conditions [2]. However, most of these methods use harmful chemicals and toxic substances, which are harmful to the environment. To solve this problem, green synthesis has become a better option. It helps protect the environment and is safer and cheaper than traditional methods because it uses microorganisms or plant extracts [4]. For example, plant extracts are used in green synthesis to make metal oxide particles. These extracts act as both reducing agents because they contain many useful molecules like phenols, lipids, carbohydrates, enzymes, and proteins, which scientists often use in their work [5].

While green synthesis using various plant extracts has been extensively studied, the use of commercial jasmine tea as a reducing agent remains underexplored. Inspired by these results, there is a possibility of making ZnO particles using commercial jasmine tea. This tea is highly favored in regions across northern and southeastern China because of its soothing fragrance and beneficial attributes. Jasmine tea is produced by combining green and black tea, followed by infusion with the fragrance of jasmine (*J. sambac*). In recent years, jasmine tea has become more and more popular, because of its

special taste and many health benefits, such as helping to control blood sugar, support the immune system, and have antioxidant effects. Liu et al., (2012) found that jasmine tea has better antioxidant power than green tea and black tea. Chen et al. (2023) and Zhang et al. (2022) discover phenolic compounds in jasmine tea have a strong ability to act as antioxidants, which helps them reduce metal ions, making the green synthesis process more effective. Given its rich phenolic content and antioxidant properties, this study aims to investigate the feasibility of utilizing jasmine tea for ZnO nanoparticle synthesis, addressing both the need for sustainable synthesis routes and readily available biomaterials.

Both green and black tea come from the same plant, called *C. sinensis* L. However, they taste and smell different, and have different chemicals because they are made in different ways [7]. Green tea is not fermented at all, while black tea is fully fermented. The main thing found in tea is called polyphenols, and they make up 20 to 35% of the dry weight. Investigations revealed that jasmine tea comprises particular volatile components, such as *cis*-3-hexene benzoate, benzyl acetate, methyl 2-aminobenzoate, linalool, (*Z*)-3-hexanol, methyl salicylate, and benzyl alcohol [8][9]. Chemical substances present in these extracts promote the transformation of metal ions into nanosized particles through diverse oxidation methods. Functional moieties, like polyphenols, are known to interact with metal ions, forming ligand complexes that act as precursors for nanoparticle generation [10].

Various scientists have conducted prior assessments on the antibacterial potential of zinc oxide particulates. Their role in inhibiting microbial expansion was evaluated. Findings confirmed that these particles are efficient in targeting harmful bacteria. ZnO nanoparticles are applied to combat organisms including the bacterial strains *E. coli* and *S. aureus*, showing maximum antibacterial strength [11]. This study aims to synthesize zinc oxide nanoparticles using jasmine tea extract as a green reducing agent. The synthesized particles will be characterized using XRD, SEM-EDX, and PSA. Furthermore, their antibacterial activity will be assessed against *E. coli* and *S. aureus* using the microdilution method to determine their efficacy.

2. Materials and Methods

2.1 Materials

Materials involved: (1) zinc acetate (Zn $(CH_3COO)_2).2H_2O$ ≥98% acting as the zinc source (Sigma-Aldrich); (2) jasmine tea (commercial tea bags); (3) purified water utilized as the reaction medium.

2.2 Jasmine Tea Extract

An amount of 5.00 g jasmine tea obtained from commercial tea bags (bought at a grocery store) was placed transferred into a vessel and stirred with 50 mL of deionized water. It was then simmered at nearly 70 °C for an hour, left to cool, and filtered threefold. The infusion was refrigerated at 4 °C until further use.

2.3 Synthesis of ZnO

Different concentrations of jasmine tea extract were introduced into a zinc acetate solution (0.2 M in water). The intention was to create compositions with distinct volumetric ratios (v:v) of 1:3 and 1:2 for the jasmine tea extract. Following this, the combinations were oven-dried at 80 °C overnight and then calcinated at 400 °C for two hours to produce ZnO particles with a white hue. Accordingly, the ZnO samples obtained were denoted as Z1 for the composition derived from the 1:3 jasmine tea extract-to-zinc acetate ratio and Z2 for that derived from the 1:2 ratio.

2.4 Data Analysis

The analysis through X-ray diffraction (Rigaku Miniflex) was utilized to inspect the crystal phase and grain dimensions, utilizing Cu K-alpha rays (1.5406 Å) under standard lab conditions of 40 kV and 40 mA, scanned across a 2θ interval between 20° and 80°. The surface morphology and elemental analysis of ZnO particles were analyzed with Scanning Electron Microscopy combined with Energy Dispersive X-ray Spectroscopy (SEM-EDX) on a Phenom ProX Desktop unit. Particle sizing was done through a PSA (Beckman Coulter LS 13 320). Microdilution was applied to assess antimicrobial action, defining the lowest concentrations that inhibit and eradicate bacterial presence.

3. Result and Discussion

Several experiments have documented the production of ZnO using either green or black tea; in this work, the employed material is a combined formulation of both teas present in a commercial jasmine tea bag.

3.1 X-Ray Diffraction (XRD) Result

The crystal structure and crystallinity of Z1 and Z2 sample were studied. **Figure 1** shows the XRD patterns of Z1 and Z2. The diffraction pattern matches precisely with standard data from (JCPDS) card No. 36-1451.16,17,18. All observed peaks located at 2θ values of 31.78, 33.9, 36.8, 47.63, 56.67, and 62.94° align with reflections from (100), (002), (101), (102), (103), (110), and (112) of the hexagonal wurtzite zinc oxide lattice (**Figure 1**). Based on the Debye-Scherrer equation, the estimated crystallite sizes of Z1 and Z2 were 26 and 28 nm, respectively, using the intensity of the (101) diffraction.

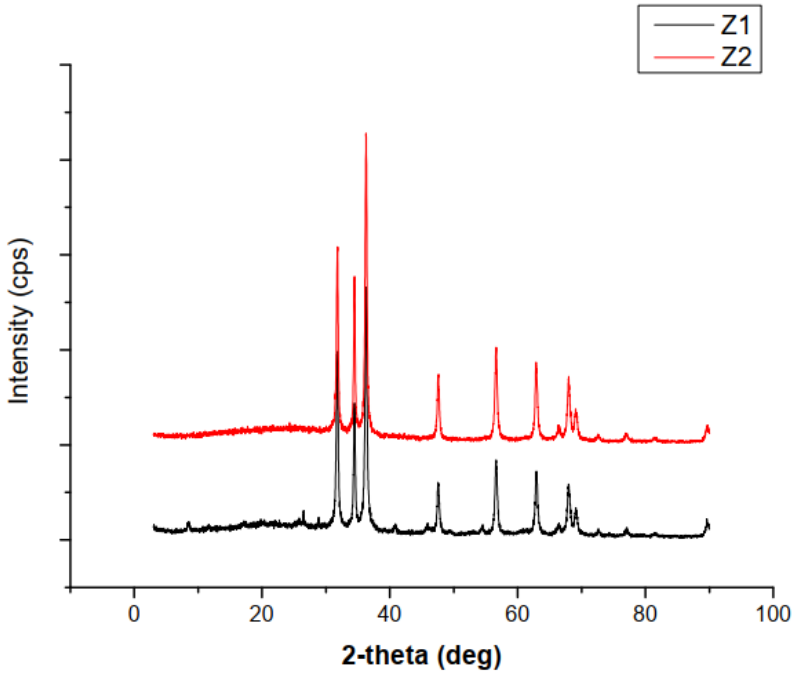

Figure 1. Diffractogram of Z1 and Z2

3.2 Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy (SEM-EDX) Result

The physical appearance of Z1 and Z2 was analyzed under a scanning electron microscope at 15,000-fold enlargement, as depicted in **Figure 2**. ZnO particles display a globular form in both Z1 (**Figure 2a**) and Z2 (**Figure 2b**); yet Z1 exhibits a less consistent shape than Z2, attributed to particle aggregation. According to the EDX output (**Figure 3**), strong responses from Zinc and Oxygen indicate the existence of Zinc in oxide condition. **Table 1** lists the element makeup for Z1 and Z2.

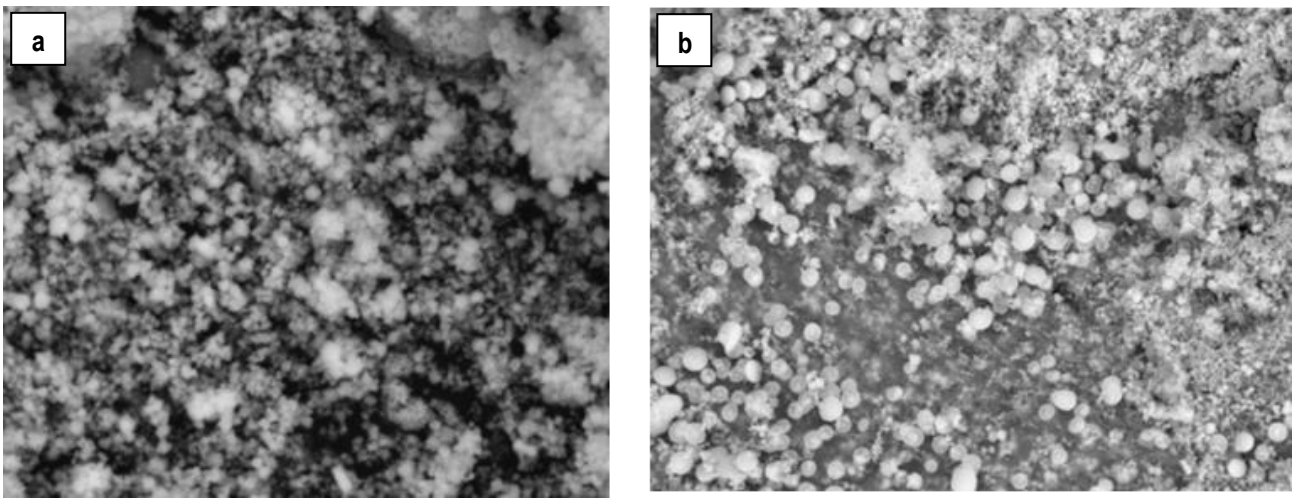

Figure 2. **a)** SEM of Z1 and **b)** SEM of Z2

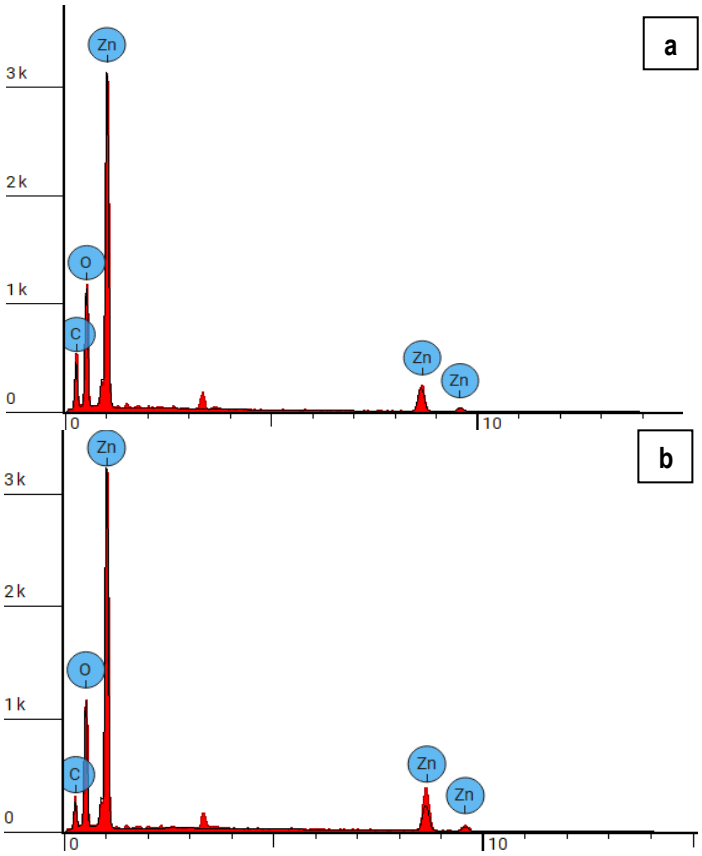

Figure 3. a) EDX spectra of Z1 and **b)** EDX spectra of Z2

Table 1. Elemental composition of Z1 and Z2

ZnO particles	Element composition (%)		
	C	O	Zn
Z1	17.6	25.2	57.2
Z2	11.5	25.8	62.7

3.3 Particle Size Analyzer (PSA) Result

The particle size distribution of both Z1 and Z2 samples was assessed with a particle size analyzer (**Table 2**). The particle size of Z1 and Z2 is polydisperse. The average particle size is approximately 500 nm, and there is a slight difference in size, that is, a smaller size particle of Z1.

Table 2. PSA results of Z1 and Z2

ZnO particles	Average size (nm)
Z1	532
Z2	553

3.4 Antibacterial Evaluation

ZnO particle samples underwent antibacterial screening employing a dilution-based method in a 96-well microplate filled with Mueller-Hinton nutrient medium for evaluating inhibition against *Staphylococcus aureus* and *Escherichia coli*. Both Z1 and Z2 were diluted in distilled water to 1000 ppm. The tested formulations and gentamycin (as control) maintained in a 96-well format at a constant 37 °C for a total of eighteen hours. Based on the inhibition zone measurements (**Table 3**), Z1 and Z2 demonstrated limited activity toward both bacterial strains at the tested level. Antibacterial efficacy is considered strong with MIC <10 µg/mL, effective if <100 µg/mL, fair in the 100–500 µg/mL interval, mild in 500–1000 µg/mL, and ineffective when above 1000 µg/mL [12].

Table 3. MIC values of Z1 and Z2

ZnO particles	MIC	
	Staphylococcus aureus (Gram-positive)	*Eschericia coli* (Gram-negative)
Z1	1000	1000
Z2	1000	1000

4. Conclusion

The formation of Z1 and Z2 ZnO nanoparticles was accomplished using a green route involving jasmine tea extract serving as a reducing agent. Characterization using XRD shows that both ZnO samples have the desired purity. The morphology of Z1 and Z2 was spherical in shape, and there was an agglomeration formed in Z1, due to the smaller size of Z1, and this was confirmed by PSA and size calculation using the Debye-Scherrer equation from the XRD result. The bandgap of Z1 was a little bit higher than Z2 due to the different ratios of jasmine tea extract and zinc precursor. Although both samples demonstrated weak antibacterial activity (MIC = 1000 ppm), this study confirms the feasibility of using jasmine tea extract for ZnO nanoparticle synthesis. The approach introduces an eco-friendly, low-cost innovation that contributes to the advancement of green synthesis.

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