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Research Article

Synthesis and Characterization of ZnO-Nanocomposites by Utilizing Aloe Vera Leaf Gel and Extract of *Terminalia arjuna* Nuts and Exploring Their Antibacterial Potency

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Nanotechnology has found vast applications in everyday life. Use of plant extract in the synthesis of nanocomposites produces relatively less toxic and environment-friendly materials. The present study deals with the synthesis of zinc oxide nanocomposite using gel from leaves of *Aloe vera* (black *Aloe vera* (BAV) and white *Aloe vera* (WAV)) and extract from powder of nuts of *Terminalia arjuna.* Synthesized nanocomposites were then characterized by using SEM, FTIR, and UV-Vis techniques. Disc diffusion method was opted to inquire the antimicrobial ability of nanocomposites against different bacterial strains such as *Escherichia coli* (−) and *Burkholderia stabilis* (+). ZnO-BAV possessed good antimicrobial potential against both selected strains as proved from zone of inhibitions. However, ZnO-WAV and ZnO-N showed potential against E. *coli* and no response for *B. stabilis*.

1. Introduction

The study and utilization of material at atomic, molecular, and macromolecular scale is an uprising subdiscipline in different fields of science. During nanocomposite synthesis, particle size reduction of metals is a very attractive field for the researchers as it opens different opportunities to produce novel products [1]. There is a remarkable interest in the synthesis of nanoparticles as they exhibit tremendous properties such as rapid disintegration, shorter dissolution time, and organic, inorganic, and organometallic components and can be used for synthesizing nanoparticles.

Electrochemical and physiochemical nature of nanoparticles defines various areas of their applications, such as optics, photonics, chemisensitive sensing, medicine, pharmaceutics, data storage devices, ceramics, and water purification by catalysis and adsorption [1, 2]. Synthesis of nanoparticles is generally performed by following two different approaches termed as top-down and bottom-up. In the former method, the macroparticles are reduced to nanosized particles, but they are of nonuniform shape, whereas in the later approach, nanoparticles of definite size, shape, and structure are produced. Green synthesis defines the route to produce nanoparticles using less and relatively safer reagents in order to protect the environment [3, 4]. Enzymes and biological materials can be utilized as the capping and reducing agents [3]. Nanoparticles can be synthesized by using micro-organisms such as fungi instead of plant extract, and these microorganisms' help to reduce the metals effectively [5].

During recent years, plant-mediated synthesis of metal nanocomposites has gained noticeable popularity [6]. One significant reason is that the plant-mediated synthesis of nanoparticles is relatively faster than microorganism-based synthesis of nanoparticles [7].

It has been already reported that various techniques can be employed for the synthesis of ZnO nanopowders as thermal decomposition of organic precursor, electrodeposition, microwave-assisted techniques, spray pyrolysis, hydrothermal methods, precipitation methods, sol gel method, and use of microemulsions [8–17].

A large variety of plant materials has been used for the synthesis of metal nanocomposites, and their potential antimicrobial effects have also been reported in literature [18, 19]. In present studies, zinc nanoparticles are synthesized with the help of *Aloe vera* gel and *Terminalia arjuna* nuts.

Zinc is a strong reducing agent with a moderately reactive property [20]. ZnO nanoparticles have promising potential as an antimicrobial agent. It was observed that ZnO maintains its antibacterial tendency even after composite formation. Its antimicrobial properties include damaging the micro-organism cell by discharge of ions [21]. ZnO composites have also been used as nanofertilizer [22].

Aloe vera is a succulent plant species from the genus *Aloe*. It has cacti-like leafy structure and mostly found in African and Asian regions. It is used as general tonic for immune system, and its juice can potentially be used to treat various diseases [23, 24]. It is effective in treating lung cancer, diabetes, rheumatic arthritis, ulcers, skin burns, and indigestion; it is used as an anti-inflammatory agent and has cosmological importance [25–29].

Terminalia arjuna belongs to genus *Terminalia*. This plant is usually located around riverbanks or near the derelict riverbank in South Asia [30–32]. The main chemical constituents of *Terminalia* nuts include triterpenoids, tannins, saponins, gallic acid, flavonoids, phytosterols, and ellagic acid [33]. Different studies showed that *Terminalia arjuna* plant exhibits antioxidant potential, hypotensive, anti-inflammatory, antiatherogenic, antimutagenic, anticarcinogenic, and gastroproductive effects. Extracts of this plant has proved it useful against coronary heart diseases.

2. Materials and Methods

2.1. Materials. All the chemicals are used in the present study: carbon tetrachloride, silver nitrate, zinc acetate, sodium hydroxide, and chromic acid were obtained from Sigma Aldrich. Furthermore, double distilled water was used for preparing all the solutions.

2.2. Collection of Plant Material. In this study, two plants having medicinal significance were selected, i.e., *Aloe vera* and *Terminalia arjuna.* Two varieties of dried *Aloe vera* gel (commercially available marked as black *Aloe vera* (BAV) and white *Aloe vera* (WAV)) were purchased from the local market. The dried plant material was ground to fine powder and sieved through 20 ASTM and kept in a jar for further use.

Almost dried nuts of *Terminalia arjuna* were directly collected from the trees grown at Quaid-e-Azam Campus, University of the Punjab, Lahore. The nuts were washed, dried, and grounded using a ball mill and sieved through 20 ASTM. The powder was dried at 70°C and kept in an air-tight jar for further use.

2.3. Plant Extract Preparation. For the preparation of the plant extract, 5 g of dried plant material was taken separately in distilled water (100 mL). They were stirred at 100 rpm on a hot plate for 15 minutes at 70°C. This solution was filtered after cooling and used for the preparation of ZnO nanoparticles. Extract of both plant materials was prepared following the same procedure.

2.4. Synthesis of ZnO Nanocomposites. To synthesize the ZnO nanomaterial with medicinal plant extracts, initially zinc acetate (2.9 g) was dissolved in 50 mL of water. This solution thus obtained was stirred using a magnetic stirrer for 1 hour at room temperature in a conical flask. Then, 20 mL of 10% sodium hydroxide solution was slowly added, and the contents were mixed thoroughly. Now, the flask is covered after adding 50 mL of plant extract and left it for 1 hour. Then, it was placed on an orbital shaker at 100 rpm for 3 hours. Then, the contents were allowed to stand for another 30 minutes. The yellow-coloured ZnO nanocomposites, settled down at bottom, were separated either by centrifuging or by decanting off the supernatant liquid carefully. The ZnO composites were dried in an oven at 80°C for 2 hours. The scheme used is given in Figure 1.

2.5. Characterization of ZnO Nanocomposites. Composite nanoparticles of zinc were characterized by using FTIR, UV, and SEM techniques.

To study the presence of various functional groups, FTIR analysis (Perkin Elmer) was carried out in the range of 4000–400 cm^{-1} for plant extract and then compared with the plant-based ZnO nanocomposites.

For conducting the UV analysis, Labomed 3500-UVD was used to find λ_{max} of the synthesized material. They absorb the characteristic wavelengths with a little variation due to the organic molecules from plant materials acting as capping and reducing agents.

To study the surface morphology of any material, SEM analysis was conducted. To verify the formation of nanocomposites, the comparison of SEM of dried plant material and synthesized nanocomposite was studied. It reveals the change in the structural morphology that occurs during the formation of nanocomposites.

3. Results and Discussion

3.1. FTIR Analysis of ZnO-BAV. FTIR spectra of BAV-Zn indicated various bands. Weak signals at 3633 cm^{-1} are owing to the presence of N-H amines. Strong stretching vibration owing to the formation of N-H amides is found at 1533 cm^{-1}. The spectra of ZnO-BAV, ZnO-WAV, and ZnO-N are displayed in Figures 2–4.

3.2. FTIR Analysis of ZnO-N. The presence of secondary amines was displayed due to N-H amines at 3343 cm^{-1}. Strong stretching vibrational signals at 1511 cm^{-1} is owing to the formation of the N-H amide bond. Strong stretching vibration at 1362 cm^{-1} is because of alpha methyl bending.

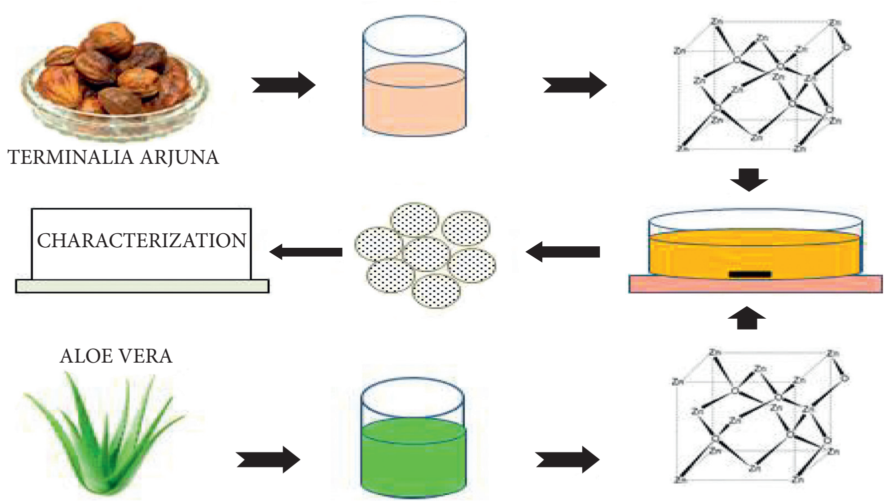

Figure 1: Scheme of synthesis of ZnO nanocomposites.

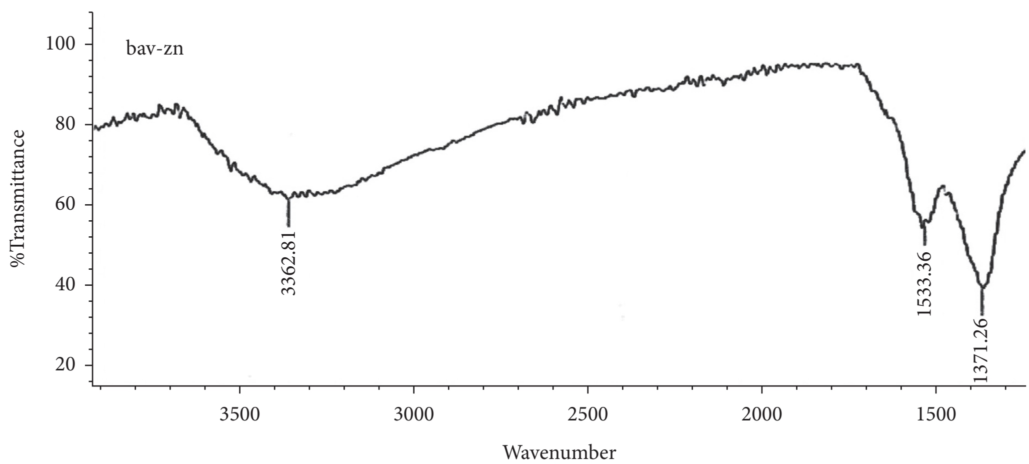

Figure 2: FTIR spectrogram of ZnO-BAV nanocomposites.

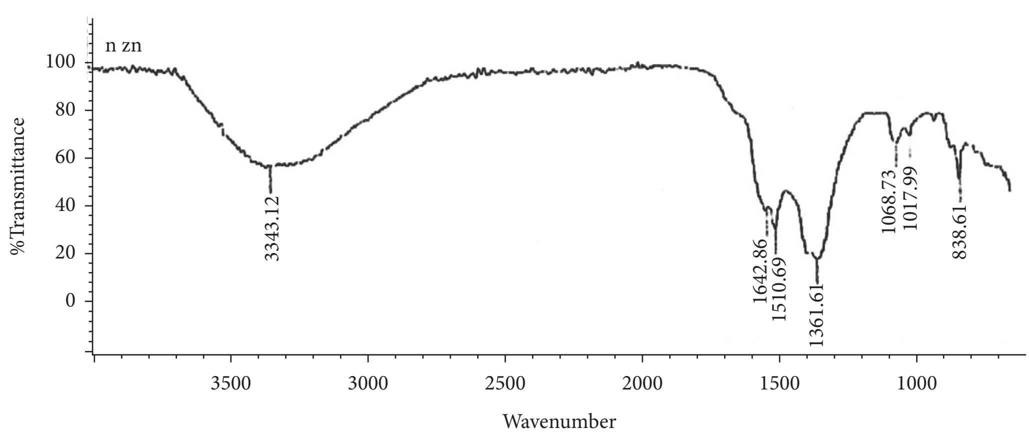

Figure 3: FTIR spectrogram of ZnO-N nanocomposites.

Peak at 1069 cm^{-1} indicated strong stretching due to oxygen-carbon bond. Band at 838 cm^{-1} shows strong stretching vibrations caused by the C-H bond. The work of Dobrucka also validates our work who found the bands are at 3243, 2168, 1383, 1599, 1076, 780, and 515 cm^{-1}. Peaks near 515 cm^{-1} can be owing to the stretching vibration of ZnO.

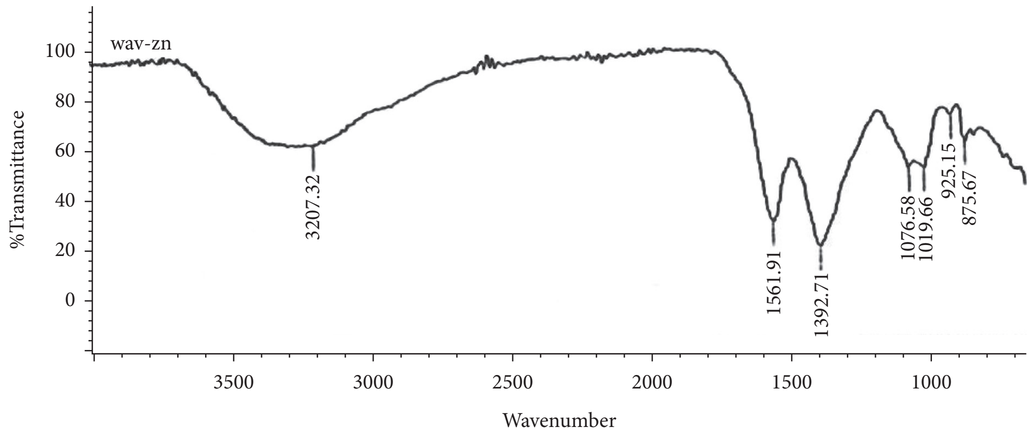

FIGURE 4: FTIR spectrogram of ZnO-WAV nanocomposites.

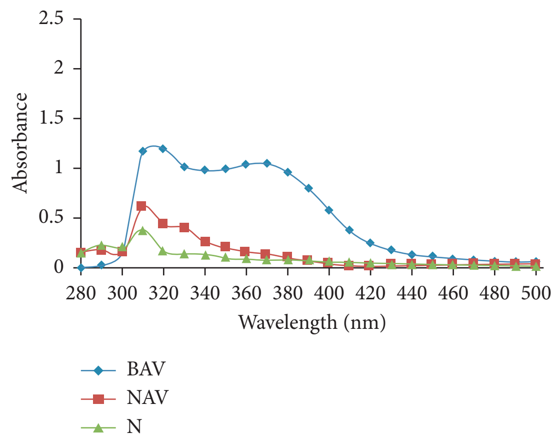

FIGURE 5: UV-Vis spectrogram of ZnO nanocomposites synthesized by BAV, WAV, and nuts.

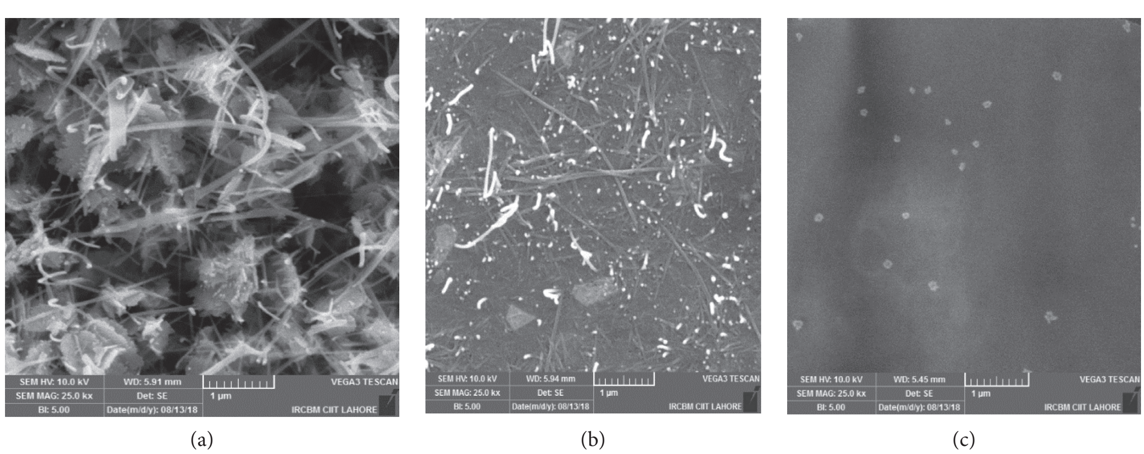

FIGURE 6: SEM images of (a) ZnO-BAV, (b) ZnO-N, and (c) ZnO-WAV nanocomposites.

Other bands at 3245 and 1599 cm^{-1} are indicating the -OH group. The peaks at 1383 and 1076 cm^{-1} may be ascribed to -C-O- and -C-O-C-stretching vibes [34].

3.3. FTIR Analysis of ZnO-WAV. In the spectrogram of ZnO-WAV, the band at 3207 cm^{-1} demonstrated the presence of amines, whereas the band at 1393 cm^{-1} is owing

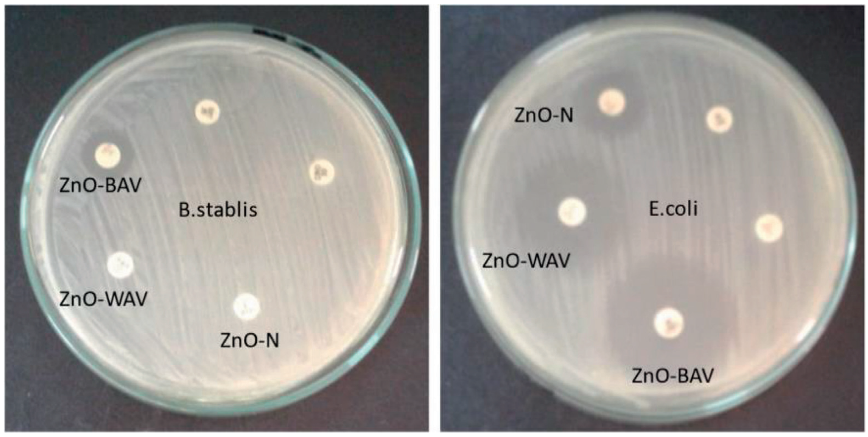

Figure 7: Images showing the application of synthesized nanocomposites of ZnO by using BAV, WAV, and N for antibacterial activity against *E. coli* and *B. stabilis*.

Table 1: Zone of inhibition produced by different ZnO nanocomposites.

Nanocomposites	Zone of inhibitions for zinc nanocomposites	
	Escherichia coli	*Burkholderia stabilis*
ZnO-BAV	0.24 ± 0.02	0.11 ± 0.01
ZnO-WAV	0.20 ± 0.02	—
ZnO-N	0.11 ± 0.02	—

to C-O-H bonding. The stretching of two O-C bonds is exhibited by the band at 1020 cm^{-1}. The analysis of Jamdagni also strengthens our spectral results, who gained FTIR peeks at 3340.6, 3258.2, 2127.8, 1641.1, 1456.7, 1362.5, 1040, 1026.8, 746.25, and 620.65 cm^{-1} for ZnO nanocomposites [34].

3.4. UV-Vis Analysis. UV-Vis spectrographs were taken in the range of 280–500 nm for ZnO nanocomposites using suitable solvents. UV absorption spectra for ZnO nanocomposites with BAV, WAV, and nuts are shown in Figure 5. It is revealed that λ_{max} is shown at 320 and 310 nm, respectively. Nearly, the same results were reported in the previous work [34].

3.5. SEM Imaging. SEM images of ZnO-nanocomposites have been performed on FEI Nova 450 NanoSEM. The shape of each Figure (Figures 6(a), 6(b), 6(c)) obtained by SEM images are fibrous-wired structure, scattered particle, and octahedral, respectively. The different surface morphology of ZnO nanocomposite revealed that ZnO-BAV showed fibrous-wired structure (~27 to 71 nm particle size), ZnO-N showed scattered particle formation (~32 to 83 nm particle size), and ZnO-WAV showed octahedral zinc composite (~29 to 75 nm particle size) as shown in Figure 6.

3.6. Antimicrobial Activity. Antimicrobial potential of synthesized ZnO-nanocomposites was investigated against two bacterial strains, i.e., *Burkholderia stabilis* and *Escherichia coli.* After preparing Petri plates using agar medium and uniformly distributing the bacterial strains over the agar surface, the disc diffusion method was applied. DMSO was used to make the solutions. The zone of inhibition in case of zinc oxide nanocomposites, as shown in Figure 7, revealed active antimicrobial potency against the selected strains of bacteria. Zone of inhibitions for ZnO nanocomposites are compared in Table 1.

4. Conclusion

Nanocomposites of zinc oxide were synthesized by using the plant extract of *Aloe vera* and *Terminalia* plants. These nanoparticles are synthesized under ecofriendly conditions with less toxic chemical production. Nanoparticles are then characterized by using different analytical techniques such as FTIR, UV-VIS, and SEM. In FTIR studies, the synthesized nanoparticles showed absorbance and bending at expected specific wavenumbers due to various functional groups which confirmed the synthesis of nanocomposites. In the UV-Vis, spectrum the synthesized products showed the maximum absorption at specific wavelength assigned for ZnO that confirms the formation of the product of interest. From SEM images, the nanoparticle's structure was further confirmed, and it shows the morphology of the nanoparticles. Then, the antibacterial potential was checked against two bacterial strains *Burkholderia stabilis* and *Escherichia coli*, and both types of nanocomposites indicated efficient antibacterial potency.

Data Availability

All data related to this work are presented in the Results section along with references.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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