ISPEC Fen Bilimleri Enstitüsü Dergisi, 2(1):33-38, 2023
ISPEC Journal of Science Institute, 2(1):33-38, 2023
DOI: https://doi.org/10.18016/10.5281/zenodo.10442807

Okra Extract-Mediated Green Synthesis of ZnO Nanoparticles: Characterization

Sabit HOROZ[1]*, Orhan BAYTAR[2], Emre BİÇER[1]
[1]Department of Engineering Fundamental Sciences, Faculty of Natural Sciences and Engineering, Sivas Science and Technology University, 58100, Sivas, Turkey
[2]Department of Chemical Engineering, Faculty of Engineering, Siirt University, Siirt, 56100, Turkey
Sorumlu Yazar (Corresponding author): sabit.horoz@sivas.edu.tr

Abstract
This study evaluates the effectiveness of okra extract as an eco-friendly approach for the synthesis of ZnO nanoparticles. The X-ray diffraction (XRD) analysis confirms the expected crystal structure of ZnO nanoparticles, while the Debye-Scherrer equation reveals their nanoscale dimensions and the resulting material property variations. The scanning electron microscopy (SEM) examination shows the presence of both homogeneous and heterogeneous surface morphologies in the nanoparticles. Additionally, the Energy-Dispersive X-ray Spectroscopy (EDX) analysis clarifies the elemental composition, shedding light on potential applications in engineering and materials science. This study aims to contribute to the advancement of eco-friendly synthesis and nanotechnology and inspire future research.

Research Article

Article History
Received : 29.10.2023
Accepted : 02.12.2023

Keywords
Okra extract
ZnO nanoparticles
green synthesis
characterization

1.Introduction

Nanotechnology has become a prominent field of research in recent years, offering groundbreaking opportunities across a wide range of applications. This interest stems from the unique properties exhibited by nanomaterials (Tran et al., 2020; Kutluay et al., 2021). Within this context, the synthesis and characterization of nanomaterials have become pivotal areas of focus for scientists and researchers alike. This study delves into the green synthesis of zinc oxide (ZnO) nanoparticles using okra extract as a natural source.

Green synthesis offers an environmentally friendly approach in the production of chemical products and materials compared to traditional methods. This method, carried out using components derived from plants, microorganisms, or other natural sources, minimizes chemical waste and enhances energy efficiency (Güngördü Solğun et al., 2018; Aswathi et al., 2023; Nguyen et al., 2023). At the same time, green synthesis has the potential to reduce environmental impacts in the production of materials used in nanotechnology (Ekinci et al., 2023).

ZnO nanoparticles are fundamental building blocks in nanotechnology (Pal et al., 2018). These nanoparticles can be designed and synthesized for various applications. ZnO nanoparticles find utility in many fields due to their semiconducting properties, including solar cells (Beek et al., 2004) LEDs (Moyen et al., 2020), power electronics (Balogun et al., 2020), and sensors (Wang et al., 2020). Additionally, their antibacterial properties make them potentially valuable in medical applications (Abd El-Kader et al., 2021). The combination of green synthesis and ZnO nanoparticles offers an exciting area for researchers aiming to enhance environmental sustainability and develop advanced technology-based products. The convergence of these two key elements can contribute to the development of green nanotechnology and reduce environmental impacts, thereby striving to leave a more sustainable world for future generations (Akintelu and Folorunso, 2020; Karthik et al., 2022).

The outcomes of this study may demonstrate the effectiveness of okra extract as a green approach for ZnO nanoparticle synthesis and emphasize the potential applications of such materials in medicine, the environment, and the energy fields. This research aspires to support advancements in nanotechnology and eco-friendly material production and serve as an inspiration for future studies. For further details on this subject, continue reading the rest of this article.

2.Results and Discussion

X-ray diffraction (XRD) is a powerful analytical technique used to unveil the intricate details of crystalline materials and their atomic structures. In essence, XRD allows us to peer into the organization of atoms within a material and discern the inherent crystal lattice. In Figure 1, we can observe the XRD diffraction patterns associated with ZnO nanoparticles. These patterns showcase distinct peaks corresponding to different crystallographic planes, such as (100), (002), (101), (102), (110), and (103) in ZnO's hexagonal lattice. This congruence between the observed diffraction patterns and the reference card, JCPDS 36-1451, verifies that the ZnO nanoparticles maintain the expected hexagonal crystal structure.

In our research, we leveraged the Debye-Scherrer equation (commonly expressed as Equation 1) to calculate the average particle size of the synthesized nanoparticles, yielding a value of 11.7 nm. This numerical output bears significant implications, indicating that the ZnO nanoparticles are, in fact, quite diminutive. Their nanoscale dimensions imply that they exhibit unique material properties that differ notably from their bulk counterparts. This phenomenon is of paramount importance, particularly in the realms of nanotechnology, catalysis, semiconductor device fabrication, and drug delivery systems. The precise control of particle size offers a multitude of possibilities for tailoring material characteristics to specific applications, potentially revolutionizing these fields.

Equation 1 (Debye-Scherrer equation), which was employed for this particle size determination, is an invaluable tool in the realm of XRD analysis. It is expressed as:

$D=(0.9*\lambda)/(\beta*\cos(\theta))$ (Equation 1)

Where:

D represents the average crystallite size.

λ signifies the X-ray wavelength.

β denotes the full width at half maximum (FWHM) of the diffraction peak.

θ stands for the Bragg angle.

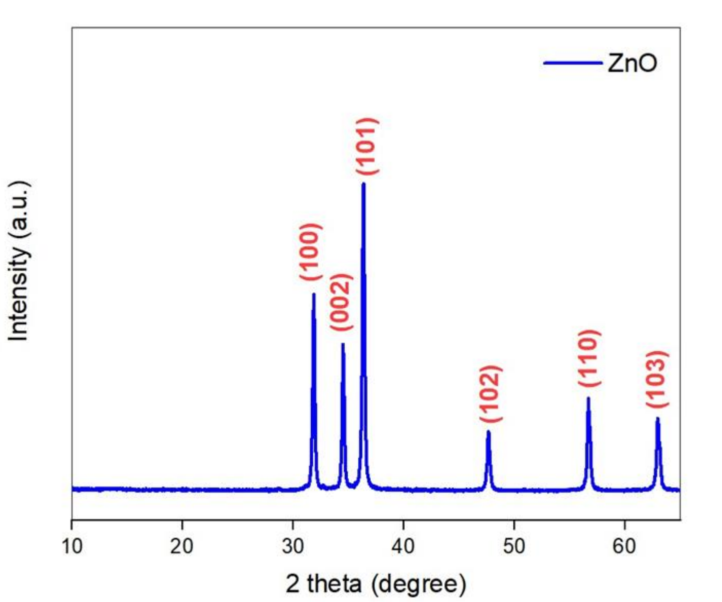

Figure 1. XRD patterns of ZnO nanoparticles.

The surface morphology of nanoparticles holds a paramount position as a critical parameter that profoundly influences their photocatalytic activity. In the realm of nanotechnology, the interplay between a nanoparticle's physical structure and its chemical reactivity is of great significance. In this study, we embarked on an exploration of the surface morphology of ZnO nanoparticles through an analysis of scanning electron microscope (SEM) images. Our goal was to gain insight into the potential effects of this morphology on the photocatalytic efficiency of these nanoparticles.

Figure 2 provides a compelling snapshot of our findings. The SEM image depicts a landscape of ZnO nanoparticles, and upon closer examination, we can discern distinct features within this microscopic world. Notably, a significant proportion of the nanoparticles appears to assume a homogeneous cubic shape, while others exhibit a spherical morphology. These observations unveil a critical aspect of nanoparticle behavior: surface morphology can be both regular and predictable, as well as heterogeneous and diverse. The prevalence of nanoparticles with homogeneous surface morphologies suggests a promising advantage from a photocatalytic perspective. The rationale behind this is rooted in the notion that such regular morphologies pave the way for a more uniform and efficient reaction surface. The orderly arrangement of atoms on these surfaces can facilitate the interaction between the nanoparticles and the substances they are meant to catalyze. Consequently, the homogeneous morphology becomes a favorable characteristic, especially when aiming for consistent and optimized photocatalytic performance.

However, it is essential to tread carefully and appreciate the nuances of nanoparticle behavior. The nanoparticles with heterogeneous surface morphologies, as illustrated in our SEM images, should not be disregarded. Under specific conditions and in particular contexts, they can offer unique advantages. The heterogeneity within these nanoparticles creates distinct regions on their surfaces with varying structural features. These diverse surface areas can lead to different reaction rates, enabling a broader spectrum of photocatalytic reactions. In essence, the nanoparticles with heterogeneous morphologies have the potential to unlock a wider range of chemical transformations, which can be particularly valuable in scenarios where multifunctionality and adaptability are key requirements.

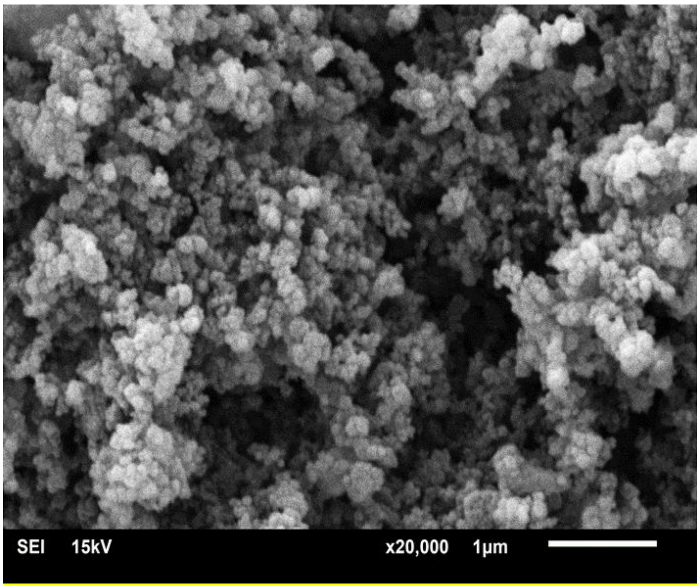

Figure 2. A SEM image of ZnO nanoparticles

Energy-Dispersive X-ray Spectroscopy (EDX) is a crucial analytical technique employed for determining the chemical composition and concentrations of elements in a given sample. Within the scope of this project, EDX measurements were conducted to carry out a detailed analysis of the elements present in ZnO nanoparticles and their respective ratios.

The resulting EDX spectra have taken center stage in this investigation, and the outcomes are visually presented in Figure 3. These spectra unveil the characteristic signatures of the elements contained within the examined nanoparticles. The results obtained from EDX measurements are notably illuminating. The elemental composition of ZnO nanoparticles is as follows: 79.17% zinc (Zn) and 20.28% oxygen (O). These findings unequivocally establish zinc oxide as the fundamental building block of ZnO nanoparticles.

These elemental composition data empower us with a comprehensive understanding of which elements are contained within ZnO nanoparticles and the exact percentage of each. This capability is of paramount importance in fields such as engineering, materials science, nanotechnology, and chemistry, as it plays a critical role in the development, characterization, and optimization of materials specifically tailored for particular applications.

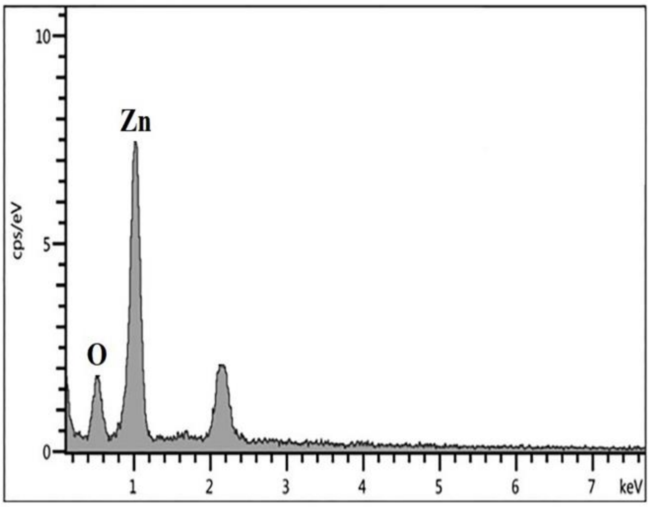

Figure 3. EDX spectrum of ZnO nanoparticles

3. Conclusions

The XRD analysis conducted in this research provided insights into the crystal structure of ZnO nanoparticles. The congruence between the observed diffraction patterns and the reference card validated the maintenance of the expected hexagonal crystal structure. Moreover, the use of the Debye-Scherrer equation enabled the precise determination of an average particle size of 11.7 nm, emphasizing the nanoscale nature of these particles. The examination of nanoparticle surface morphology via SEM unveiled a diverse landscape. While a significant proportion of the nanoparticles exhibited a homogeneous cubic shape, some displayed a spherical morphology. Furthermore, the EDX analysis confirmed the elemental composition of ZnO nanoparticles, with 79.17% zinc (Zn) and 20.28% oxygen (O).

In this context, this study not only contributes to the advancement of nanotechnology and eco-friendly material production but also serves as an inspiration for future research endeavors. The findings presented here expand our understanding of ZnO nanoparticles and their potential for diverse applications, emphasizing the importance of green synthesis, nanoscale properties, and surface morphology in shaping the future of material science and technology.

Acknowledgements

This research was supported by grants from Research Projects Unit of Sivas Science and Technology University (2022-GENL-Müh-0009).

Authors' contributions

Sabit HOROZ: Methodology, Writing - Original Draft, Validation, Investigation, Writing -review & editing, Emre BİÇER: Validation, Investigation, Orhan BAYTAR: Validation, Investigation

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

Abd El-Kader, M.F.H., Elabbasy, M.T., Adeboye, A.A., Zeariya, M.G., Menazea, A.A., 2021. Morphological, structural and antibacterial behavior of eco-friendly of ZnO/TiO2 nanocomposite synthesized via Hibiscus rosa-sinensis extract. *Journal of materials research and technology*, 15: 2213-2220.

Akintelu, S.A., Folorunso, A.S., 2020. A review on green synthesis of zinc oxide nanoparticles using plant extracts and its biomedical applications. *BioNanoScience*, 10(4): 848-863.

Aswathi, V.P., Meera, S., Maria, C.A., Nidhin, M., 2023. Green synthesis of nanoparticles from biodegradable waste extracts and their applications: a critical review. *Nanotechnology for Environmental Engineering*, 8(2): 377-397.

Balogun, S.W., James, O.O., Sanusi, Y.K., Olayinka, O.H., 2020. Green synthesis and characterization of zinc oxide nanoparticles using bashful (Mimosa pudica), leaf extract: A precursor for organic electronics applications. *Sn Applied Sciences*, 2: 1-8.

Beek, W.J., Wienk, M.M., Janssen, R.A., 2004. Efficient hybrid solar cells from zinc oxide nanoparticles and a conjugated polymer. *Advanced Materials*, 16(12): 1009-1013.

Ekinci, A., Kutluay, S., Şahin, Ö., Baytar, O., 2023. Green synthesis of copper oxide and manganese oxide nanoparticles from watermelon seed shell extract for enhanced photocatalytic reduction of methylene blue. *International Journal of Phytoremediation*, 25(6): 789-798.

Güngördü Solğun, D., Horoz, S., Ağırtaş, M.S., 2018. Synthesis of novel tetra (4-tritylphenoxy) substituted metallophthalocyanines and investigation of their aggregation, photovoltaic, solar cell properties. *Inorganic and Nano-Metal Chemistry*, 48(10): 508-514.

Karthik, K.V., Raghu, A.V., Reddy, K.R., Ravishankar, R., Sangeeta, M., Shetti, N. P., Reddy, C.V., 2022. Green synthesis of Cu-doped ZnO nanoparticles and its application for the photocatalytic degradation of hazardous organic pollutants. *Chemosphere*, 287: 132081.

Kutluay, S., Horoz, S., Şahin, Ö., Ekinci, A., Ece, M.Ş., 2021. Highly improved solar cell efficiency of Mn-doped amine groups-functionalized magnetic Fe3O4@ SiO2 nanomaterial. *International Journal of Energy Research*, 45(14): 20176-20185.

Moyen, E., Kim, J.H., Kim, J., Jang, J., 2020. ZnO nanoparticles for quantum-dot-based light-emitting diodes. *ACS Applied Nano Materials*, 3(6): 5203-5211.

Nguyen, N.T.T., Nguyen, T.T.T., Nguyen, D.T.C., Van Tran, T., 2023. Green synthesis of ZnFe2O4 nanoparticles using plant extracts and their applications: A review. *Science of The Total Environment*, 872: 162212.

Pal, S., Mondal, S., Maity, J., Mukherjee, R., 2018. Synthesis and characterization of ZnO nanoparticles using Moringa oleifera leaf extract: investigation of photocatalytic and antibacterial activity. *International Journal of Nanoscience and Nanotechnology*, 14(2): 111-119.

Tran, P., Lee, S.E., Kim, D.H., Pyo, Y.C., Park, J.S., 2020. Recent advances of nanotechnology for the delivery of anticancer drugs for breast cancer treatment. *Journal of Pharmaceutical Investigation*, 50: 261-270.

Wang, S., Jia, F., Wang, X., Hu, L., Sun, Y., Yin, G., Liu, B., 2020. Fabrication of ZnO nanoparticles modified by uniformly dispersed Ag nanoparticles: enhancement of gas sensing performance. *ACS Omega*, 5(10): 5209-5218.