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BIOSYNTHESIS AND CHARACTERIZATION OF ZnO NANOPARTICLES WITH BEET EXTRACT (*Beta vulgaris* L.) AS LATENT FINGERPRINT IDENTIFICATION

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ABSTRACT

The uniqueness and permanence of patterns make fingerprints one of the most significant forensic tools for individual identification. The issue is that conventional fingerprint powders, frequently used today, pose serious health and environmental risks due to their use of toxic chemicals. This novel study utilizes sustainable and innovative techniques to investigate the effectiveness of beetroot fruit extract for latent fingerprint visualization. Zinc oxide (ZnO) nanopowders were synthesized using a green synthesis method, having beet fruit extract as an aqueous solvent. For applications on porous and non-porous surfaces, the fabricated ZnO was characterized using Fourier Transform Infrared (FT-IR) spectroscopy, Scanning Electron Microscopy (SEM), and Energy Dispersive X-ray (EDX) analysis up to October 2023. Thirty samples were provided to perform latent fingerprint analysis. The results show that ZnO nanopowders synthesized using beet fruit extract could provide safe, non-destructive, and efficient visualization of the latent fingerprints. Of the six fingerprint patterns examined, the most common was the Plain Whorls pattern, which represented 47% of prints identified. These results highlight beet fruit extract's natural potential and efficacy as a contrast agent for imaging latent fingerprints. This clean approach can provide a novel alternative for forensic biology, characterized by low toxicity, sustainability, and high efficacy, which can lead to a safe forensic practice.

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INTRODUCTION

Fingerprints are one of the most common identification methods in the modern era [1]. Not two identical fingerprints existed in the world [2]; each individual possessed a different fingerprint pattern [3]. Due to the identification factor, fingerprints were extensively utilized in several fields, such as security, forensic, and personal identification.

Fingerprints were arguably the most important part of a security system. The identification was based on fingerprints, which are widely used as biometric identifiers in today's digital world to access smart devices like mobile devices and smart homes and control lighting and doors [4]. Also, right from the fingerprints, many countries are used to verify their fingerprints when issuing different passports or other important documents.

Latent fingerprints, invisible traces left by individuals, serve as crucial evidence in criminal investigations and personal identification [5]. Detecting and retrieving latent fingerprints effectively remains a significant challenge in forensic science [6]. Traditional methods for visualizing fingerprints often rely on synthetic chemicals that can degrade fragile evidence and pose environmental hazards. The growing need for environmentally sustainable practices in forensic investigations has led to exploring alternative methods. This study addresses the pressing demand for eco-friendly solutions using natural materials like beetroot extract. Beetroot provides stable, vibrant pigments without generating toxic byproducts, offering an innovative approach to forensic science that aligns with global sustainability goals and safer investigative practices [7].

The biosynthesis and characterization of ZnO nanoparticles using plant extracts combine advancements in nanotechnology with forensic science. Research has demonstrated the potential of ZnO nanoparticles synthesized through green biosynthesis methods for latent fingerprint detection. These nanoparticles offer significant advantages due to their high surface area, antimicrobial properties, and strong photocatalytic activity, which enhance the sensitivity and accuracy of identification techniques. ZnO nanoparticles facilitate improved evidence visualization, contributing to more effective and precise forensic analyses. This study characterizes the morphology, size, and optical properties of ZnO nanoparticles to evaluate their application in forensic science. By integrating nanotechnology with green chemistry, this research offers the dual benefit of advancing forensic methodologies while maintaining environmental sustainability [8].

Recent studies on synthesizing ZnO nanoparticles using plant extracts showed great potential for latent fingerprint identification. By transitioning to natural products for these processes, it eliminates the need for toxic chemicals and reduces environmental harm. Furthermore, the plant-based synthesis approach is inexpensive, biocompatible, and helpful in the superior application of the NPs in forensic science. This method and the reason for the efficiency of these ZnO-NPs in latent fingerprint identifiers can be demonstrated by structural investigations, such as size, shape, and optical properties, which are a bounce of forensic applications [9].

Biologically synthesized ZnO nanoparticles from plant extracts can be considered a prominent progress in forensic science. These nanoparticles can stop using untrusted neurotoxin nanomaterials by using plant synthesis, which is beneficial and reliable for developing efficient techniques. This approach provides safer, more effective, and environmentally friendly methods for detecting latent fingerprints, thereby advancing public safety and law enforcement. These advancements keep with the international focus on sustainability and green practices in our forensic investigations.

Herbal materials, including suji leaves (*Pleomele angustifolia*), have been studied for latent fingerprint visualization [3]. Studies revealed suji leaves to have excellent green color contrast for fingerprint visualization at particle sizes of 100 and 200 mesh (ground). The fingerprints of those samples were classified according to blood type, gender, and ethnicity, and the circular shapes made the largest ratio of patterns [10]. On the other hand, turmeric powder (Curcuma longa) has been researched as a visualizing agent for latent. Upon analyzing 30 samples, 10% of the samples exhibited radial loop, 70% ulnar loop, 3.3% twinned loop, and 16.6% plain whorl pattern of fingerprints [11]. A similarly conducted study used gambier powder, shown in the study, to produce fingerprint images with a brownish color that stood out from the background when the particle sizes of the powder were ground down to the finest four particle sizes [12]. Latent fingerprint identification has also been investigated in other plants: papaya leaves [12], lime [13], and dragon fruit extract [14]

Due to its vivid pigments, especially betacyanin, beet fruit extract has emerged as a potential nature-based substance used in food applications, with a bright red color and substantial dyeing ability. Such traits render beet extract a potential option when applied in forensic settings, especially for visualizing latent fingerprints [15], [16]. The use of beetroot fruit extract in this study aims to expand the application of the best fruit extract to latent fingerprint visualization to create a unique, modern, and sustainable approach to forensic techniques. Beet fruit extract reflects both natural benefits and the progress in forensic analysis that addresses the issues of environmentally friendly methods for public security and law enforcement.

METHODS

1. Chemicals and Materials

The apparatus used includes: 1) as many as two beakers (Phyrex) 500 mL, 250 mL, and 100 mL, 2) magnetic stirrer (Thermo Scientific), 3) a mercury thermometer, 4) an analytical balance (Fujitsu), 5) glinder, 6) stative, 7) furnace, 8) oven-each one piece, 9) glass funnel (Phyrex) 99 mm and 50 mm-each two pieces, 10) filter paper (Whatman No. 1) as much as one piece, 11) 50 mm porcelain cup as much as five pieces, 12) scissors (Joyco), 13) magnifying glass (Joyco), 14) mobile phone camera (Makita). 15) 1 piece, 16) 50 mm porcelain cup as many as five pieces, 17) scissors (Joyco), 18) magnifying glass (Joyco), 19) cell phone camera (Macro Samsung Galaxy A73), 20) Black Marabou Feather Duster (Sirchie), 21) FT-IR (Fourier Transform Infrared Spectroscopy), and 22) SEM-EDX (Scanning Electron Microscopy-Energy Dispersive X-Ray).

The materials used include: (1) beet fruit as much as 30 grams, (2) aquabides as much as 1 liter, (3) zinc nitrate hexahydrate ($Zn(NO_3)_2.6H_2O$) with a concentration of 98%, (Smart-Lab) as much as 24 grams, (4) latex gloves as much as one box, (5) Finger Print Hinge Lifter (Sirchie brand, USA) as much as 20 pieces, (6) HI-FI Olcano Latent Print Powder (Sirchie brand, USA) as much as one piece, and (7) porous surface media (black cardboard and oil paper) and non-porous surface media (aluminum foil, glass preparation, compact disk) to taste. Beet fruit samples have been purchased in quantities of as much as 1 kg, whereas the beet fruit was purchased from Simpang Limun Market in Medan, North Sumatra.

2. Extraction of Beet fruit (*Beta vulgaris* L.)

Freshly harvested 30 g of beet fruit were washed with aquabides to remove contaminants. Then, they were cut finely into pieces of two-finger lengths with a knife. The material was chopped into a 2.5 cm uniform size to facilitate their and the drying process. Beet fruit pieces were dried in an oven at 82°C for 6 hours.

A beaker containing 2 grams of red beet fruit powder was added to 100 mL of aquabides. Finally, a magnetic stirrer enhanced the extraction process by diffusing analytes from the bulk solution to the extraction phase. This was done at 70°C for 10 minutes and then at 80 °C for another 10 minutes since the processing and storage process influenced phenolic compounds and antioxidant activity. Many highlighted factors were identified, such as phenolic compounds, food processing methods, storage conditions, and the importance of phenolic compounds as antioxidants [17].

The solution was filtered through filter paper to separate the filtrate from the residue of the beet fruit extract solution, and the filtrate was used to synthesize ZnO nanoparticles. The filtration time greatly impacted the value of the resulting water flux [18].

3. ZnO Nanoparticles Synthesis

Zinc nitrate (4 g) was dissolved in 85 mL of red beet fruit extract, and the mixture was magnetically stirred for 1 hour. To accelerate the reactions, ensure solutions were more uniform, and improve the agglomeration of nanoparticles, the solutions were continuously stirred with a magnetic stirrer during the entire synthesis [19]. The solution was subsequently incubated at 60°C in a water bath for 1 hour.

The appearance of a colored solution signals the formation of ZnO nanoparticles [20]. They became increasingly brownish at increasing temperatures, suggesting smaller particles [21]. A subsequent color change of the solution in the following few hours will indicate that ZnO salt's bioreduction into nanoparticles has occurred [22]. The mixture was heated up to 150°C with a magnetic stirrer to see if the solution became suspended or precipitated, which indicates that the metal ion and the functional groups of the metabolite compounds that acted as reducing agents reached their critical solubility point.

The formation of the paste was a sign of completion of the bioreduction process on the nanoparticles, and it was known that the amine groups in the extracted beetfruit acted as natural bases in the processes of $Zn(OH)_2$ formation. The calcination at 400°C can result in the formation of ZnO nanoparticles. High-temperature heating broke many organic bonds, which caused the degradation of organic compounds in ZnO and produced pure ZnO nanoparticles.

4. Nanoparticle Characterization

The ZnO nanoparticles (1-2 mg) were added to a 10 mg KBr pellet, compressed, and used for the creation of a clear sample disk. This sample was subsequently placed into an FT-IR to be analyzed in the 4000-400 cm^{-1} range. The overall objective was to indirectly determine the functional groups in the bioactive compounds in the beet fruit extract that are involved in the formation of nanoparticles.

Nanoparticles were prepared and suspended in water, and a drop of the resulting centrifuged suspension was placed on a sample holder. The remainder was allowed to sit until the solvent evaporated, and then it was dried under a mercury lamp for at least five minutes. Afterward, the morphology of the nanoparticle was obtained by scanning the sample with SEM, and EDX was employed to detect elemental composition in the nanoparticles.

5. Development of Latent Fingerprints

Thirty subjects were selected at random for latent fingerprint identification. Respondents were directed to wash their hands with soap and air-dry them before touching sweaty face areas, like the forehead, nose, chin, and cheeks. ZnO nanoparticle powder was synthesized with the help of beet fruit extract to stick to fingerprints and make them visible on different media.

ZnO nanoparticles were synthesized using an extract of beet fruit, which were applied separately to each medium followed by a gentle and careful rub in one direction. Latent fingerprints were lifted with a Finger Print Hinge Lifter. Respondents pressed their fingerprint patterns on two media types as a function of the surface: porous (black cardboard and oil paper) and non-porous (aluminum foil, compact discs, and microscope slides). Respondents were then asked to spread the powder of ZnO biosynthesis carefully. Lastly, fingerprint results were photographed/images.

RESULTS AND DISCUSSION

1. Preparation of Extract of Beet fruit

The best fruit was washed with aqua bikes, cut into small pieces, ground, and dried. The drying process was done in an oven at 82°C for 6 hours. Beet fruit powder was obtained by grinding intact beet fruit using a Glinder grinder for 5 minutes (Figure 1).

Figure 1. Beet Fruit Powder

Beet fruit powder (ground) 2 g was mixed in two cycles to stabilize the extraction process so that analyte diffusion with the solvent from the bulk solution would lead to the extractant phase from the beet fruit. Beet fruit leaves were utilized for the biosynthesis of ZnO nanoparticles. Nanoparticles which are very small (smaller than 100 nanometers [23]) materials that can be derived from metals, metal oxides, semiconductors, polymers, carbon materials, and organic compounds

This signaled a change in color, the first showing results of the presence of physio-chemical properties on changing a solvent aquabides on stirring the mixture of ($Zn(NO_3)_2.6H_2O$) with the extract of beet fruit, where this was designated as an early marker for the production of the nanoparticles that were beginning to form. A mix was prepared at 150°C for 10 minutes under magnetic stirring to obtain a brownish-black and suspended solution, indicating the bioreduction of the nanoparticles was complete. The initial heating at 400°C was carried out to purify the remaining impurities, such as CO_2, and then the calcination process produced beige-colored biosynthesis with beet fruit extract from ZnO nanoparticles.

2. FT-IR Spectrophotometry as a Characterization of ZnO Nanoparticles

The FT-IR spectra of ZnO nanoparticles synthesized with beet fruit extract are presented in Figure 2. The FT-IR spectrum of beet fruit nanoparticles, flavonoids, and tannins displayed 10 peaks at wave number 3304.21 cm-1, attributed to the stretching vibration of the -OH group. These peaks typically signal hydroxyls, as in water or alcohols, and the phenol function is directly on an aromatic ring. The hydroxyl group of alcohol, a type of organic compound, is covalently bonded, making the properties of alcohol different from hydroxide. In contrast to others, the properties of alcohols make them much more similar to water's.

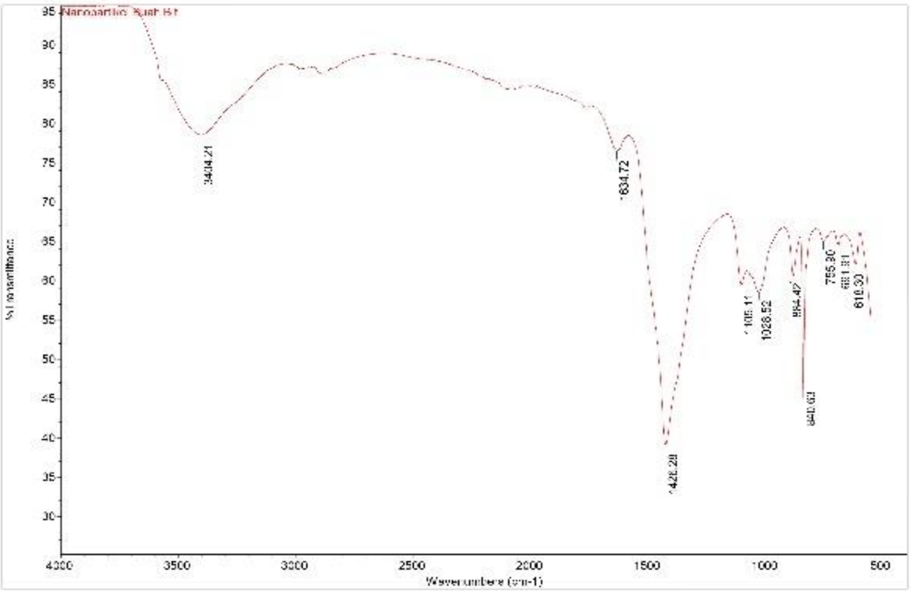


Figure 2. FT-IR Spectrum of ZnO Nanoparticles

The peak at the wavelength of 1634.72 cm^{-1} was mostly linked to the bending vibration of carbonyl (C=O) or water molecules. Blue spectra were more intense than red spectra with few carbonyl groups. The surface area of the plant can be calculated using SEM analysis [24] at a wavelength of 1412.28 cm^{-1}; this peak can also be associated with the bending vibrations of CH_2 or CH_3 groups in organic molecules [25].

At a distance of this peak at 1105.11 cm-1, this peak is frequently related to extending vibration and stretching of C-O made in liquor, ester, or carboxylic acid. The fiber at 1028.62 cm-1 wavelength is attributed to vibrations of C-O or Si-O-Si groups in silica. The 755.95 cm^{-1} wavelength was related to the bending of the vibrations of the C-H groups out of the plane of the aromatic system. It represents the wavelength of 618.93 $cm^{-1,}$ possibly indicating vibrations of Si-O groups in silica or C-H bonds in the aromatic molecule. The wavelength results from the interaction of ZnO compounds with a mixture of aquabide solvent with biosynthesized beet fruit extract. Figure 3 represents the reaction mechanism of synthesis of beet fruit (-ZnO) nanoparticles.

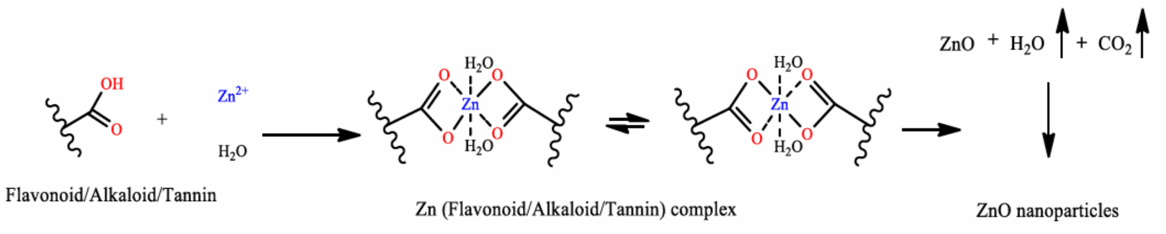


Figure 3. Reaction Mechanism for the Synthesis of Beet Fruit ZnO Nanoparticles

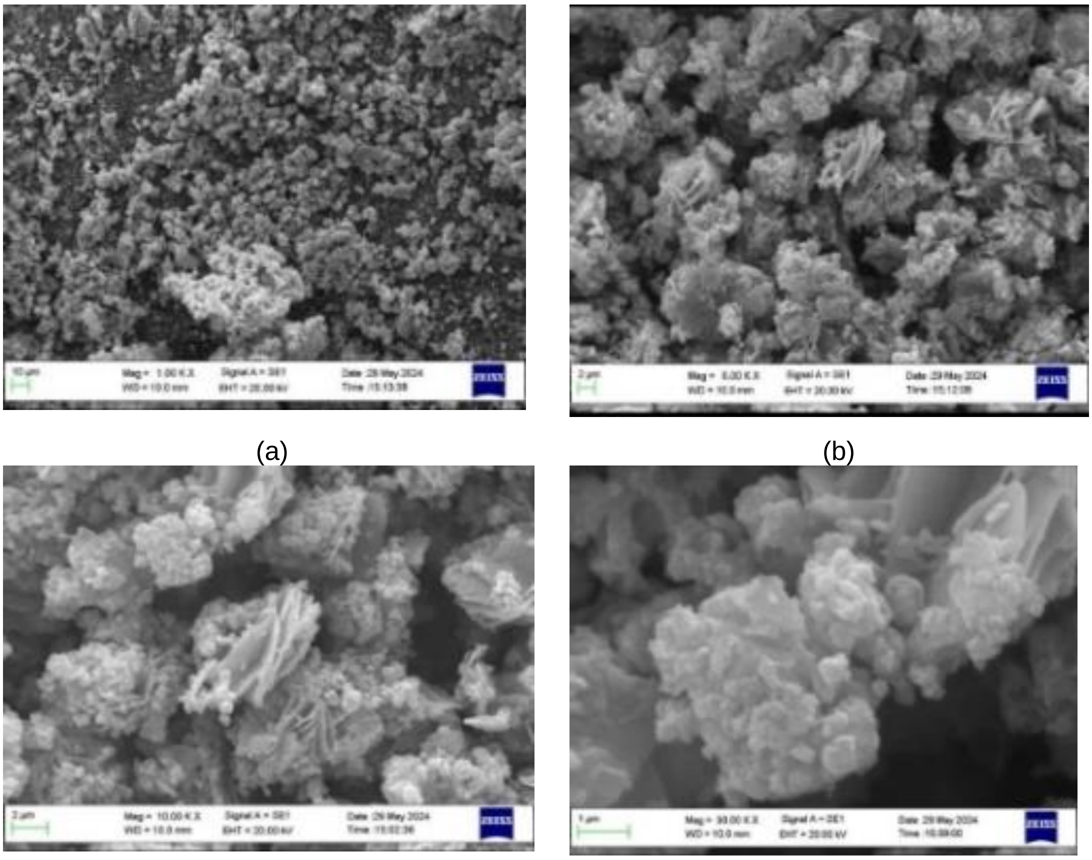
The hydroxyl group becomes ketone, and the secondary metabolite compounds of beet fruit leaf extract are oxidized Zn ions because the hydrogen atoms are released. It was observed that when flavonoid, alkaloid, or tannin molecules, which possess free OH groups, interact with ZnO, zinc complexes are formed. Finally, the calcination process was done at 400°C to obtain pure ZnO nanoparticles after the process [25], [26]. According to FT-IR analysis, there was no difference among all treatments, and it confirmed the chemical composition of ZnO, which has been carried out from [20], [7], [26].

3. Characterization with SEM EDX

SEM results of surface morphology of zinc oxide nanoparticles synthesized with beet fruit extract at magnifications of 1,000, 5,000, 10,000, and 30,000 times, using SEM.

The findings of the surface morphology of synthesized ZnO nanoparticles using beetroot extract depict a fascinating view of the physical and chemical properties of materials at different magnifications. Various magnification levels of SEM analysis provide more information about the structure and arrangement of the ZnO particles.

Ergo, at 1,000 times the magnification, the surface morphology of ZnO nanoparticles exhibited some common physical and chemical characteristics, such as rough particle size or a surface that may not be prominently identified. Relevant studies showed that beet fruit extract might be a morphology-modifying agent in synthesizing metal oxide nanoparticles, e.g., ZnO. The use of beet fruit extract affected the size and morphology of ZnO-NPs, with beet fruit extract producing smaller and more uniform nanoparticles than those produced using conventional synthesis methods [27].



(a) (b) (c) (d)

Figure 4. Morphology of ZnO Nanoparticles Based on SEM with Magnification a) 1,000; b) 5,000; c) 10,000; and d) 30,000

Scanning electron microscopy at 5,000x magnification did confirm a more uniform distribution of ZnO particles, demonstrating that some of these particles had a distinct crystal structure. This behavior is consistent with previous results that showed that the use of beet fruit extract in ZnO synthesis resulted in a better-defined morphology and size distribution of the particles [28].

Surface Imaging of ZnO with SEM in the case of ZnO at 10,000x magnification indicated that the surface of the ZnO nanoparticles was made up of irregular particles or crystals. This irregular shape could be due to the effect of beet fruit extract on the growth and crystal orientation of ZnO nanoparticles [29].

The nanoparticle's surface morphology appeared as spherical particles with a rough surface texture at 30,000x magnification. It was demonstrated that some organic materials, including beet fruit extract, could contribute to the change of the morphologies to spherical globules and roughening of the surface, affecting the optical and functional features of ZnO nanoparticles [30].

The average diameter of ZnO nanoparticles was observed as 52,058 nm, synthesized with the help of beet fruit extract.

While the large surface area of these nanoparticles is beneficial for various applications, the strong van der Waals and electrostatic forces between nearby nanoparticles can promote rapid agglomeration. Such agglomeration may substantially impact the nanoparticles' properties, affecting their optical, chemical, and physical performance, and may even reduce their effective surface area [29].

Approaches to prevent agglomeration include modification of the surface or addition of biologically derived surfactants; it is proved that chemically modified beet fruit extract is quite effective in alleviation and providing an adequate distribution of particles. These strategies are essential for ensuring the stability and activity of ZnO nanoparticles in various applications, including catalysis, sensors, and nanoelectronics [31].

Thus, despite the larger surface area of bZnO-NPs, which makes it advantageous for applications like catalysis and sensors, the agglomeration phenomenon must be considered the key challenge. Agglomeration is also a controllable factor, and the previous literature data indicate that size, morphology, and dispersion control of nanoparticles with the use of suitable stabilizers or surfactants are potential solutions to the agglomeration issue that will enhance the performance and reproducibility of ZnO nanoparticles.

The diameter size of the nanoparticles was analyzed further, as seen in Figure 5 underneath.

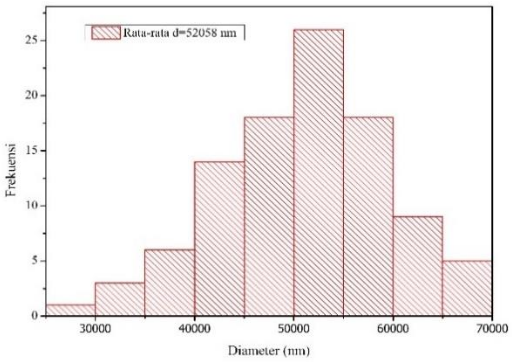


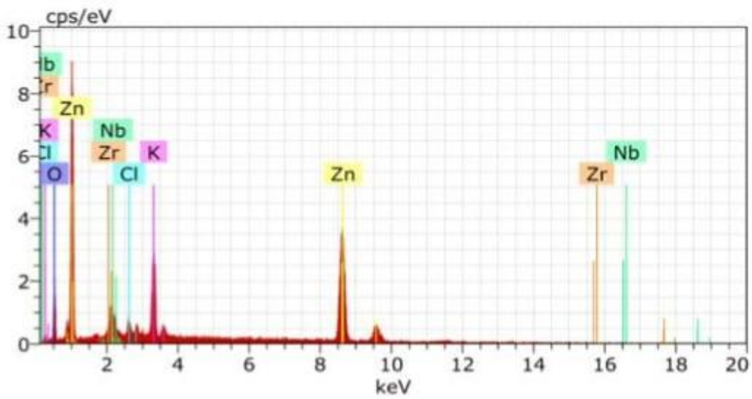
Figure 5. Diameter Size Distribution of ZnO Nanoparticles

Homogeneous particle size distribution of beet fruit extract synthesized ZnO nanoparticles with PDI value close to zero confirmed the successful synthesis of uniform ZnO nanoparticles. It has significant repercussions on the nanoparticles' physical stability and capacity in different technological applications.

Regarding the ZnO particle size distribution, a low PDI suggests that an efficient size control was achieved in the selected synthesis technique, leading to a narrow distribution of uniform and stable particles. The present green synthesis method, which employs plant extracts, offers a promising route to obtain high homogeneity of the particle size distribution, accurately meeting the expectations of a wide variety of technological applications where particles with uniform quality are required.

4. EDX (Energy Dispersive X-ray) Characterization

The EDX characterization technique used to identify the ester and composition found in the nanoparticles is shown in Figure 6.



Spectrum: Acquisition

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Oxygen	K-series	10.25	12.82	35.79	2.20
Chlorine	K-series	1.02	1.27	1.60	0.08
Potassium	K-series	9.81	12.27	14.01	0.37
Zinc	K-series	52.01	65.02	44.42	1.57
Zirconium	L-series	2.77	3.46	1.69	0.19
Niobium	L-series	4.13	5.16	2.48	0.23
	Total:	79.99	100.00	100.00	

Figure 6. EDX spectra

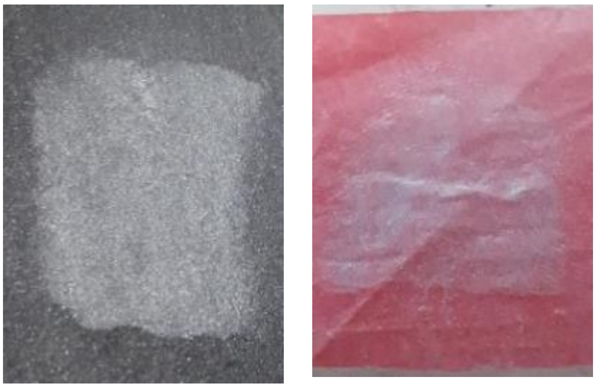
Elemental mapping results of EDX spectra of ZnO NP consist of elements like Oxygen (O), Chlorine (Cl), Potassium (K), Zinc (Zn), Zirconium (Zr), and Niobium (Nb) [16], [17]. The fact that some amount of beet fruit extract was detected as a contaminant in the ZnO nanoparticles indicated the complexity of mechanisms and difficulties in the green synthesized nanomaterial production process.

Latent Finger Print Identification Application

Some of the 30 respondents' fingerprint prints that have been collected as records were identified to identify the types of fingerprint patterns, which are shown in Figure 7 and Figure 8.

(a) (b) (c)

Figure 7. Visualization of Latent Fingerprints on Non-Porous Surfaces: (a) Prepared Glass; (b) Aluminum Foil; (c) CD



(a) (b)

Figure 8. Visualization of Latent Fingerprints on Porous Surfaces: (a) Black Cardboard Paper and (b) Oil Paper

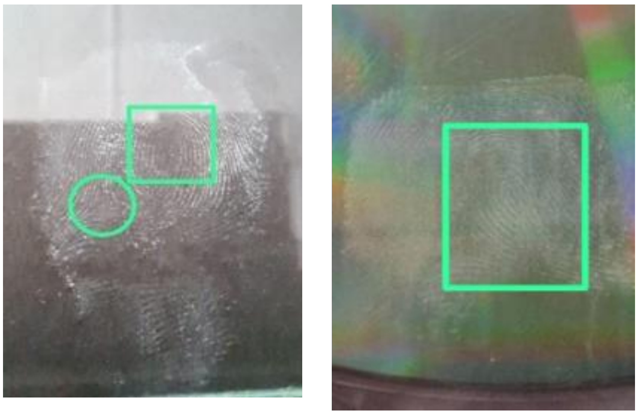
Well-defined ridge characteristics were seen in the fingerprints recovered from the porous and non-porous media. Nanoparticles are very useful for identifying latent fingerprints on such media, as the particle size of nanoparticles will behave differently as a mechanism for identification. The quality and clarity of fingerprint ridge patterns are largely determined by how that silver nanoparticle sticks to the surface of the latent fingerprints.

These smaller nanoparticles have a greater surface area than larger particles, allowing them to bind more easily to the grooves and ridges in fingertip prints. This enhances the resolution and contrast of the final image, making forensic identification easier. For porous media like paper or cloth, smaller nanoparticles hold further advantages by penetrating and diffusing uniformly into the porous structures of the medium, which greatly improves the overall quality of visualization of fingerprints.

The significant potential of ZnO nanoparticles in fingerprint imaging. This can be ascribed to non-covalent and hydrophobic interactions between nanoparticles and fingerprint residues, which are abundant in sebaceous secretions containing water-insoluble organic compounds [11], [32]. This study pioneered the study of green-synthesized nanoparticles as a forensic application in Indonesia. Moreover, nanometer scale ZnO nanoparticles obtained using green chemistry demonstrated better imaging quality when applied on a porous medium, emphasizing the importance of particle size in obtaining sharper and clearer fingerprints [33].

Moreover, locally available plant extracts are also studied for the synthesis of nanoparticles. For instance, Teak (*Tectona grandis*) leaf extracts 39 40 plants naturally extracted ZnO-NPs can better optimize visual resolution on different forensic media [34]. This suggests that effective forensic identification methods must precisely control nanoparticle size and synthesis techniques.

Nanoparticle technology has greatly progressed in characterization and imaging techniques in Indonesian forensic science. Techniques such as energy-dispersive X-ray (EDX) and scanning electron microscopy (SEM) have been utilized to investigate nanoparticle-fingerprint surface and substrate media interactions. Such techniques offered significant information on adjusting the detection limit and the sharpness of the rainbow image through ZnO nanoparticles, leading to improved forensic applications [35].



(a) (b)

Figure 9. Types of Fingerprint Patterns: (a) Plain Whorls with Delta and (b) Plain Whorls Without Delta

Fingerprint patterns on various media have been studied to assess their frequency and distinctive features. Of the 30 respondents, six fingerprint patterns were noticed: plain, double loop whorls, plain arches, ulnar loops, tented arches, and radial loops. Two forms for the plain whorls pattern were present (with delta (9) and without delta (9)). Figure 10 shows this was the most common of the identified patterns, accounting for 47% of all collected samples. The distinctive central circular-formed characteristics delineating this type of fingerprint are found on each side of the fingertip, making it easy to recognize and useful for categorizing fingerprints during forensic examination. On the other hand, double-loop whorls were the least frequent pattern seen and were detectable in only 3% of samples. They are (two interlocking/mangling) loops.

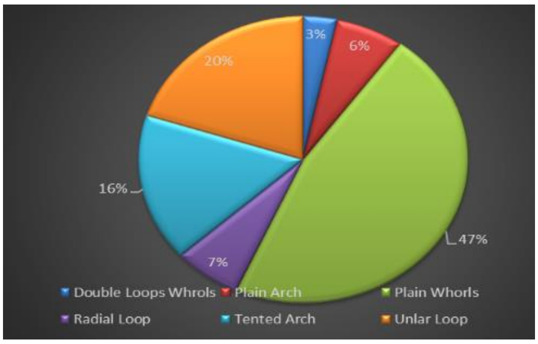


Figure 10. Percentage of Fingerprint Patterns

Recent research on applying artificial intelligence to image processing and fingerprint pattern analysis has also advanced the classification and recognition of even less typical fingerprint patterns, such as the double loop whorl [36]. Also, the latest research on genetic and environmental impact on fingerprint patterns has provided further perspective on fingerprint diversity and its implications in forensic science [37].

Identifying humans through fingerprint patterns, including the characteristics and frequency of occurrence of plain whorls, is important in forensic science, personal identification, and medical diagnostic purposes. The presented findings offer critical groundwork for new forensic identification technologies, integration of advanced imaging approaches, and fidelity to rapid and comprehensive forensic analysis.

CONCLUSION

These findings indicate that the biosynthesis and properties of ZnO are suitable for safer, non-destructive, and efficient latent fingerprint detection with beet fruit extract. The most notable result of latent fingerprint development is that the percentage of Plain Whorls fingerprint pattern is the highest among the other patterns, which means that 47 percent of the pattern found.

Optimization of biosynthesis parameters to obtain ZnO nanoparticles: optimization of the interaction between bioactive compounds in beet fruit extract and zinc ions. Beet fruit extract used in this methodology may help explore green output materials for the synthesis of nanoparticles with the desired dimensions/boundary shape. FT-IR spectrophotometry and SEM-EDX techniques were used to thoroughly analyze the synthesized ZnO nanoparticles' structure, composition, and morphology. The characterization results indicate that the nanoparticles possess a uniform size distribution and chemical composition, consistent with the properties of ZnO.

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REFERENCES

[1] V. T. Siringoringo, D. Pringgenies, and A. Ambariyanto, “Kajian Kandungan Logam Berat Merkuri (Hg), Tembaga (Cu), dan Timbal (Pb) pada Perna viridis di Kota Semarang,” *J Mar Res*, vol. 11, no. 3, pp. 539–546, Aug. 2022, doi: 10.14710/jmr.v11i3.33864.

[2] D. Y. Pratiwi, “Dampak Pencemaran Logam Berat (Timbal, Tembaga, Merkuri, Kadmium, Krom) Terhadap Organisasi Perairan dan Kesehatan Manusia,” 2020, doi: 10.24198/akuatek.v1i1.28135.

[3] W. D. Prasetyo, “Sintesis Nanomaterial Perak dengan Kontrol Terhadap Bentuk dan Ukuran,” *Jurnal Teknologia,* vol. 1, no. 1, 2018.

[4] F. F. Azhar, “Pemanfaatan Nanopartikel Perak Ekstrak Belimbing Wuluh Sebagai Indikator Kolorimetri Logam Merkuri,” *Jurnal Ipteks Terapan*, vol. 13, no. 1, p. 34, May 2019, doi: 10.22216/jit.2019.v13i1.3614.

[5] L. Rahmidar, H. Al Fatih, and A. Sulastri, “Pemanfaatan Nanopartikel Logam Mulia untuk Mengukur Kadar Logam Berat dalam Berbagai Sampel Cair,” *PENDIPA Journal of Science Education*, vol. 4, no. 3, pp. 70–74, Oct. 2020, doi: 10.33369/pendipa.4.3.70-74.

[6] H. Atika Ariyanta, W. Dan, and S. Priatmoko, “Preparasi Nanopartikel Perak dengan Metode Reduksi dan Aplikasinya Sebagai Antibakteri Penyebab Luka Infeksi,” *J. Chem. Sci*, vol. 3, no. 1, 2014, [Online]. Available: http://journal.unnes.ac.id/sju/index.php/ijcs

[7] P. S. Yerragopu, S. Hiregoudar, U. Nidoni, K. T. Ramappa, A. G. Sreenivas, and S. R. Doddagoudar, “Chemical Synthesis of Silver Nanoparticles Using Tri-sodium Citrate, Stability Study and Their Characterization,” *Int Res J Pure Appl Chem*, pp. 37–50, Mar. 2020, doi: 10.9734/irjpac/2020/v21i330159.

[8] H. Barani and B. Mahltig, “Microwave-Assisted Synthesis of Silver Nanoparticles: Effect of Reaction Temperature and Precursor Concentration on Fluorescent Property,” *J Clust Sci*, vol. 33, no. 1, pp. 101–111, Jan. 2022, doi: 10.1007/s10876-020-01945-x.

[9] S. J. Yu, Y. G. Yin, and J. F. Liu, “Silver nanoparticles in the environment,” *Environmental Science: Processes & Impacts,* vol. 12, no. 1, pp. 78-92, 2013, doi: 10.1039/c2em30595j.

[10] N. Rahayu, G. Gusrizal, and N. Nurlina, “Ekstrak Umbi Bawang Dayak (Eleutherine Palmifolia (L.) Merr.) Sebagai Pereduksi Ion Perak Dalam Sintesis Nanopartikel Perak,” 2020. [Online]. Available: http://jurnal.untan.ac.id/index.php/IJoPAC

[11] R. N. Ridwan, G. Gusrizal, N. Nurlina, and Santosa. Sri Juari, “Sintesis dan Studi Stabilitas Nanopartikel Perak Tertudung Asam Salisilat,” *Indonesian Journal of Pure and Applied Chemistry*, vol. 3, no. 1, pp. 83–90, 2018.

[12] S. Qurrataayun, Y. Rifai, H. Rante, K. Kunci, : Biosintesis, and C. Citratus, “Sintesis Hijau Nanopartikel Perak (AgNP) Menggunakan Ekstrak Daun Serai (Cymbopogon Citratus) Sebagai Bioreduktor,” *Original Article MFF*, vol. 26, no. 3, pp. 124–128, 2022, doi: 10.20956/mff.v26i3.21047.

[13] S. Kasim, P. Taba, Ruslan, and R. Anto, “Sintesis Nanopartikel Perak Menggunakan Ekstrak Daun Eceng Gondok (Eichornia crassipes) Sebagai Bioreduktor,” *KOVALEN: Jurnal Riset Kimia*, vol. 6, no. 2, pp. 126–133, Sep. 2020, doi: 10.22487/kovalen.2020.v6.i2.15137.

[14] R. Nurbayasari *et al.*, “Biosintesis dan Karakterisasi Nanopartikel ZnO dengan Ekstrak Rumput Laut Hijau Caulerpa sp. Biosynthesis and Characterization of ZnO Nanoparticles with Extract of Green Seaweed Caulerpa sp,” *Jurnal Perikanan Universitas Gadjah Mada*, vol. 19, no. 1, pp. 17–28, 2017.

[15] M. K. Alqadi, O. A. Abo Noqtah, F. Y. Alzoubi, J. Alzouby, and K. Aljarrah, “PH effect on the aggregation of silver nanoparticles synthesized by chemical reduction,” *Materials Science- Poland*, vol. 32, no. 1, pp. 107–111, 2014, doi: 10.2478/s13536-013-0166-9.

[16] S. Yanti, M. Syaiful Arif, B. Yusuf Program Studi Kimia, F. Matematika dan Ilmu Pengetahuan Alam, U. Mulawarman Jalan Barong Tongkok No, and G. Kelua, “Sintesis Dan Stabilitas Nanopartikel Perak (Agnps) Menggunakan Trinatrium Sitrat,” in *Prosiding Seminar Nasional Kimia 2021*, 2021, pp. 142–146.

[17] M. S. Arif, R. Ulfiya, Erwin, and A. S. Panggabean, “Synthesis silver nanoparticles using trisodium citrate and development in analysis method,” in *AIP Conference Proceedings*, American Institute of Physics Inc., Sep. 2021, doi: 10.1063/5.0059493.

[18] E. Ahangar, “The pH Role in Nanotechnology, Electrochemistry, and Nano-Drug Delivery,” *Iranian Journal of Chemistry and Chemical Engineering,* vol. 41, no. 7, pp. 2175-2188, 2022, doi: 10.30492/ijcce.2022.121271.4009

[19] Y. Qin, X. Ji, J. Jing, H. Liu, H. Wu, and W. Yang, "Size control over spherical silver nanoparticles by ascorbic acid reduction," *Colloids Surf A Physicochem Eng Asp*, vol. 372, no. 1–3, pp. 172–176, Dec. 2010, doi: 10.1016/j.colsurfa.2010.10.013.

[20] I. N. Oktavia and S. Sutoyo, "Review Artikel: Sintesis Nanopartikel Perak Menggunakan Bioreduktor Ekstrak Tumbuhan sebagai Bahan Antioksidan," *Unesa Journal of Chemistry,* vol. 10, no. 1, pp 37-54, 2021, doi: 10.26740/ujc.v10n1.p37-54.

[21] A. KURT and Y. ÇELİK, "Synthesis of Quasi-Shperical Silver Nanoparticles by Chemical Reduction Route Using Different Reducing Agents," *Konya Journal of Engineering Sciences*, vol. 8, no. 4, pp. 828–838, Dec. 2020, doi: 10.36306/konjes.700622.

[22] Y. Hu, J. Ge, D. Lim, T. Zhang, and Y. Yin, "Size-controlled synthesis of highly water-soluble silver nanocrystals," *J Solid State Chem*, vol. 181, no. 7, pp. 1524–1529, Jul. 2008, doi: 10.1016/j.jssc.2008.02.028.

[23] D. Susanthy, S. J. Santosa, and E. Sri Kunarti, "The synthesis and stability study of silver nanoparticles prepared using p-aminobenzoic acid as reducing and stabilizing agent," *Indonesian Journal of Chemistry*, vol. 18, no. 3, pp. 421–427, Aug. 2018, doi: 10.22146/ijc.29312.

[24] T. Mudalige, H. Qu, D. Van Haute, S. M. Ansar, A. Paredes, and T. Ingle, "Characterization of Nanomaterials: Tools and Challenges," in *Nanomaterials for Food Applications*, Elsevier, 2018, pp. 313–353. doi: 10.1016/B978-0-12-814130-4.00011-7.

[25] M. T. Alula, L. Karamchand, N. R. Hendricks, and J. M. Blackburn, "Citrate-capped silver nanoparticles as a probe for sensitive and selective colorimetric and spectrophotometric sensing of creatinine in human urine," *Anal Chim Acta*, vol. 1007, pp. 40–49, May 2018, doi: 10.1016/j.aca.2017.12.016.

[26] J. V. Rohit and S. K. Kailasa, "5-Sulfo anthranilic acid dithiocarbamate functionalized silver nanoparticles as a colorimetric probe for the simple and selective detection of tricyclazole fungicide in rice samples," *Analytical Methods*, vol. 6, no. 15, pp. 5934–5941, Aug. 2014, doi: 10.1039/c3ay42092b.

[27] R. Adriansyah and M. Lutfi Firdaus, "Analisis Hg^{2+} dengan Menggunakan Nanopartikel Perak (NPP) Sebagai Indikator Kolorimetri dengan Metode Spektrofotometri," *Jurnal Pendidikan dan Ilmu Kimia*, vol. 1, no. 2, pp. 136–143, 2017.

[28] M. Avissa and M. Alauhdin, "Selective Colorimetric Detection of Mercury(II) Using Silver Nanoparticles-Chitosan," *Molekul*, vol. 17, no. 1, pp. 107–115, Mar. 2022, doi: 10.20884/1.jm.2022.17.1.5597.

[29] R. M. Napitupulu, D. Julia, and A. S. Panggabean, "Validasi Metode Penentuan Mn dalam Oli Lubrikan dengan Metode Pengenceran Langsung Menggunakan Spektrofotometer Serapan Atom," 2019.

[30] A. Susanto, T. Mulyani, and S. Nugraha, "Validasi Metode Analisis Penentuan Kadar Logam Berat Pb, Cd dan Cr Terlarut dalam Limbah Cair Industri Tekstil dengan Metode Inductively Coupled Plasma Optical Emission Spectrometry Prodigy7," *Jurnal Ilmu Lingkungan*, vol. 19, no. 1, pp. 191–200, Apr. 2021, doi: 10.14710/jil.19.1.191-200.

[31] N. Angger Ratnawati, A. Tri Prasetya, and Endah Fitriani Rahayu, "Validasi Metode Pengujian Logam Berat Timbal (Pb) dengan Destruksi Basah Menggunakan FAAS dalam Sedimen Sungai Banjir Kanal Barat Semarang," *J. Chem. Sci*, vol. 8, no. 1, 2019, [Online]. Available: http://journal.unnes.ac.id/sju/index.php/ijcs

[32] S. A. Sari and D. Hawari, "Biosynthesis of ZnO Nanoparticles using Lime Leaf Extract (Citrus auraantifolia) for Identification of Latent Fingerprints," *JKPK (Jurnal Kimia dan Pendidikan Kimia),* vol. 7, no. 2, pp. 171–180, 2022, doi: 10.20961/jkpk.v7i2.62090.

[33] S. Ahmad, D. Permana, F. Pratama and Y. Yusuf, "Green Synthesis of Zinc Oxide Nanoparticles from Local Sources and Their Potential in Forensic Fingerprint Analysis," *Indonesian Journal of Forensic Science and Technology*, vol. 8, no. 1, pp. 45-54, 2023, doi: 10.1007/978-981-99-4028-8_8.

[34] Senthilkumar, N., Nandhakumar, E., Priya, P., Soni, D., Vimalan, M., & Potheher, I. V. "Synthesis of ZnO nanoparticles using leaf extract of Tectona grandis (L.) and their anti-bacterial, anti-arthritic, anti-oxidant and in vitro cytotoxicity activities". *New Journal of Chemistry*, vol. 41, no. 18, pp. 10347-10356, 2017, doi: 10.1039/C7NJ02664A.

[35] R. K. Verma, V. Nagar., V. Aseri., and B. Mavry, "Zinc oxide (ZnO) Nanoparticles: Synthesis Properties and their Forensic Applications in Latent Fingerprints Development," Materials Today Proceedings, vol. 69, no. 7, 2022. doi: 10.1016/j.matpr.2022.08.074

[36] Z. S. Naser., H. N. Hiyam., A. S. Ahmed., M. S. Taha., M. M. Hashim, "Artificial Neural Network-Based Fingerprint Classification and Recognition," *Revue d'Intelligence Artificielle*, vol. 37, no. 1, pp 129, 2023, doi: 10.18280/ria.370116.

[37] Y. Gülekçi, "Effects of Environmental Factors on Fingerprint Development," *European Journal of Science and Technology,* no. 32, pp. 463-470, 2021, doi: 10.31590/ejosat.1039397